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HYPERLINKED INDEX

THEME 1 – INNOVATION SUPPORT SERVICES

Innovation Support Services / ISS (found in the literature under different labels such as extension and advisory services, intermediary organisations, etc.), conceived as an integral part of Agricultural (Knowledge and) Innovation Systems (AKIS/ AIS), face theoretical and practical challenges. Such challenges relate to our current understanding that, on the one hand, innovation involves the successful combination of 'hardware', 'software' and 'orgware' and, on the other hand, that successful innovations are usually based on an integration of ideas and insights from multiple stakeholders engaged in networks. The latter implies that innovation processes are dependent on dynamics in networks; they are affected by complex inter-dependencies, unintended and unforeseen developments and interactions and may well be conflictive. Therefore, there is a sustained interest in inventing new ways to build innovations and the need for more robust theories, methodologies and tools.

The necessity to deal with interactions between heterogeneous and interdependent stakeholders who do not necessarily share objectives, knowledge, values or practices implies that the role of newly recognized actors (who have been variously been called innovation brokers, intermediaries and free actors), stimulating the mutual learning process, is crucial. In such constellations ISS intermediaries (advisors) still play an important role, but different from what usually was assumed before. This implies the change of paradigm (i.e. the shift from transfer to 'intermediation') and new roles of advisors as facilitators / brokers stimulating and facilitating the process of learning with stakeholders in networks (networking, linking, conflict management, vision building, etc.). In this respect they need to properly utilise participatory and collaborative methodologies for the co-generation, adaptation, and use of innovations at scale.

NEW CHALLENGES FOR INNOVATION SUPPORT SERVICES TO IMPROVE COCOA QUALITY AND SUSTAINABILITY IN CAMEROON

Syndhia Mathé[a,b,c], Guillaume Fongang Fouepe Hensel[d], Martial Sonfack[d], Temple Ludovic[a,e], Jean Abega Ndjana[f]

[a] INNOVATION, Univ Montpellier, CIRAD, INRA, Montpellier SupAgro, Montpellier, France.
[b] CIRAD, UMR INNOVATION, Yaoundé, Cameroun.
[c] International Institute of Tropical Agriculture (IITA), Yaoundé, Cameroun.
[d] University of Dschang, Dschang, Cameroun.
[e] CIRAD, UMR Innovation, Montpellier, France.
[f] University of Dschang, Dschang, Cameroun.

Introduction

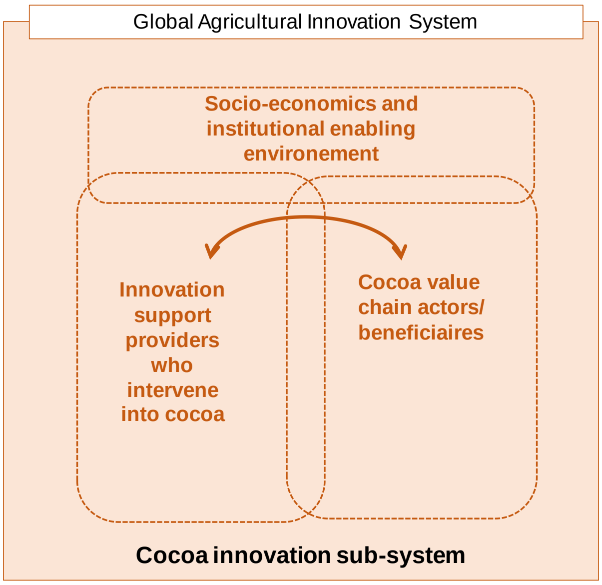
With 241,000 tons produced, Cameroun is the fifth cocoa producer in the African continent. The provision of support services for cocoa sectors experienced transformation since the beginning of the 90's. In fact, with liberalization, the cocoa sector suffered from the effects of the disengagement of the State in production and post-harvest support, and in regulation of the cocoa market and prices. A decline in cocoa quality production volumes has resulted from this situation. In a context of competitive cocoa world market, the strategy of increase quality and thus reputation of Cameroonian cocoa provides lucrative opportunities in terms of development of niche markets. In fact, cocoa quality and sustainability are major issues for Cameroon in particular due to the discount of Cameroonian cocoa on international markets. The inadequacy of phytosanitary treatments coupled with poor fermentation, drying and storage conditions have led to a drop of the quality of Cameroonian cocoa, which was rejected from European ports in 2013 because it contained traces of polycyclic aromatic hydrocarbons (PAHs) (Bagal et al. 2013). Unlike Cote d'Ivoire and Ghana, which set a guaranteed price for cocoa producers, Cameroon's cocoa marketing system is liberalized. The National Office of Coffee and Cocoa (ONCC) each day publishes an indicative price, based on the London Stock Exchange's cocoa price, that is used as reference for negotiations. These negotiations of cocoa prices occur at various levels and conduct to consider various national prices : (1) farm-gate price (which is the price received by the cocoa farmer), (2) the Free-on-Board price (FoB) which is the term of sale under which the price invoiced or quoted by a seller includes all charges up to placing the goods on board a ship at the port of departure specified by the buyer (Laven et al. 2016). Other prices are negotiated at national level based on the transactions among intermediaries involved in cocoa value chain (Coaxers and Licensed buyers). Even if Cameroonian farmers and farmer's organizations have a generally low bargaining power and are consequently mostly price-takers (Laven et al. 2016).Two important variables also play in negotiation of farm-gate cocoa price: the quantity and quality of cocoa (Laven et al. 2016). The higher the quantity, the higher the price; the better the quality, the higher the price. Additionally, sustainability issues could be an argument in the future due to Global warming issues on deforestation. Laven et al. (2016) identify also the location of the community as a variable that affect the price due to accessibility issues. In this paper, we are focusing on the question of quality and sustainability of cocoa beans production and particularly on the support of innovations oriented into the improvement of both areas. The quality of the cocoa beans influences the final chocolate flavor. The attributes of cocoa beans quality has been defined by the World Cocoa economy: *well fermented, thoroughly dry and free from smoky or broken beans abnormal or foreign odors and any evidence of adulteration, reasonably uniform in size, reasonably free from broken beans, fragments and pieces of shell, and be virtually free from foreign matter* (Levai et al. 2015). At farm level these attributes are guaranteed by appropriate and adequate post-harvest processing (Levai et al. 2015). Our focus is oriented on the existence of the innovation services dedicated to support improvement of cocoa quality and sustainability through the identification and characterization of providers and services provided, environment in which these services are provided and the beneficiaries of these services. In a first part, we present our framework based on Agricultural Innovation System (World Bank 2006), which has guided our research. In the second part, we present the specific characteristics of Cameroon cocoa innovation sub-system. We finish by discussing the challenges to support cocoa quality and sustainability-based innovations.

1. Conceptual framework based on innovation sub-system analysis

1.1. Composition of an agricultural innovation sub-system

We adopt through SERVinnov project the widely recognised concept of Agricultural Innovation Systems (AIS); which is a "*network of actors, organizations or individuals together with supporting institutions and policies in the agricultural and related sectors that bring existing or new products, processes, and forms of organization into social and economic use, including policies and institutions (formal and informal) which shape the way these actors interact, generate, share and use knowledge as well as jointly learn*" (World Bank 2006). While AIS has mostly been recognised as national systems from a normative perspective, innovation processes do occur at multiple levels and within specific fields of the agricultural sector so that not necessarily all AIS components are mobilised in each case. Within our work, we intend to identify the relevant scale and related/interconnected actors where AIS is operationalised in order to support agricultural and agrofood innovations. Various approaches are developed to define the relevant level that fit to address problem with agriculture and agrofoods systems, especially through approaches based on sub-system of AIS (Klerkx et al. 2017, Labarthe et al. 2018, Pigford et al. 2018). Scholars suggest to perform structural approach at the sub-system level (e.g. research and education, agricultural advisory services, private firms) to obtain an in-depth understanding of one or more sub-systems (Klerkx et al. 2017). In cases where an AIS is targeted a regional, sectoral and value chain, it is best regarded as "an innovation sub-system" (IsubS). We therefore define an IsubS as a partial view of the broader AIS operating at a regional (province, district), (sub) sectoral or commodity level (cocoa, horticulture, organic sector etc.), while at the same time, recognizing the whole AIS actors and their interactions occurring within this subsystem boundary. Adapting the framework developed by TAP (2016), we define the sub-system through three main components: (1) innovation support service providers, (2) the actors of the value chain who are mainly beneficiaries/clients of the innovation support services and in some cases also service providers and (3) the enabling environment which includes socio-economic and institutional aspects (Figure 1).

Figure 1. Cocoa innovation sub-system



Source: Adapted from TAP (2016)

1.2. Typology of services and service providers

Within the context of increasing services in economy, targeted literature on service provision is developed to better characterize and address services. Various categories of services exist in parallel with the classification of goods. Services can be characterized as natural/free (e.g. ecosystem services) or economic which mean produced by human activities. In our context, we are interested in innovation support services (ISS) which are economic services dedicated to support innovation particularly in agriculture and agrofoods systems. An innovation support service, as discussed in the economic and agricultural extension literature (Faure et al. 2012, Labarthe and Laurent 2013), is "*by its nature, an ISS is immaterial and intangible and involves one or several support service providers (ISP) and one or several beneficiaries in activities in which they interact to address a more or less explicit demand emerging from a problematic situation and formulated by the beneficiaries, and to co-produce the services aimed at solving the problem. The interactions aim at achieving one or several beneficiaries' objectives based on the willingness to enhance an innovation process, i.e. fostering technical and social design, enabling the appropriation and use of innovations, facilitating access to resources, helping transform the environment and strengthening the capacities to innova*te" (Mathe et al. 2016). Based on this definition, seven categories of services have been identified with examples of tools related to each category (Table 1).

Table 1. Generic ISS categories, description of activities and examples of tools and methods per category

ISS category	Brief description of activities that make up the ISS category	Tools and methods which form the basis of service activities
Knowledge awareness and exchange	Activities contributing to knowledge awareness, dissemination of scientific knowledge or technical information	*posters, official documents, databases, brochures, banners, fairs, field visits, policy briefs, guidelines, technical reports, thesis report etc. to share and exchange knowledge*
Advisory, consultancy and backstopping	Advisory, consultancy and backstopping activities aimed at solving problems and co-construction of solutions on actors' demand	*A case of visit and advisory, guidance on the job, support to problem-solving*
Demand articulation	Services targeted to connect actors to market	*price organized to award specific product, support to establishing project exposé*
Networking, facilitation and brokerage	Services to organize networks; improve relationships between actors, to align services, all activities aimed at strengthening collaborative and collective action.	*innovation fair with round tables to allow people to discuss together (not just disseminating information), establishing contacts, maintaining platforms and social media devices, acting as a mediator to solve a conflict/ to solve problems*
Capacity building	The services comprise the provision of classical training and of experiential learning processes.	*training on leadership, on management and planning, on how to manage a cooperative, how to work collectively, technical training etc.*
Enhancing access to resources	Services enhancing the acquisition of resources for the innovation process (access to inputs facilities and equipment and funding)	Examples of resources acquired as a result of the enhancing services may include inputs (fertilizers, seeds), funds,

		access to market and acquisition of certification status
Institutional support for niche innovation, and scaling mechanisms	institutional support (incubators, experimental infrastructures, etc.), support for the design and enforcement of norms, rules, funding mechanisms, taxes, and subsidies etc.	*A survey to check if laws are followed, support actors to comply with the procedures/process, deliver certification, provide new authorization to implement new activities that were forbidden before*

Source: Adapted from Faure et al. (2019)

Various actors who are involved into innovation accompanying provide these services. Table 2 presents the generic typology of the actors identify into the literature.

Table 2. Generic types of service providers

Generic type	Specific types
Public organisations	Ministries and parastatal (e.g. national and or regional authorities), public universities and education bodies, Research institutions
Private organisations	Consultancy companies, Commercial companies, Banks and insurance companies, Co-operatives etc.
Third sector farmer-based organisations	Farmer based groups, Professional sector associations, Inter-professional organisations
Third sector civil society-based organisations	Civil society organisations, charity groups; denominational institutions, etc.
Informal service providers	Family members, friends, colleagues, Local authorities, Neighbours etc.

Source: Adapted from Mathe et al. (2016); Knierim et al. (2015); Labarthe and Laurent (2013); Birner et al. (2009)

1.3. Service beneficiaries or clients of ISS

Within the literature, several terms are used to name the recipient of a service provision: Labarthe and Laurent (2013) report that the following 'agent A and B', 'beneficiary and supplier' and 'user' are the most conventional expressions from the economic theory. All the terms have some connotations, be it economical (client = customer), psychological (client = patient) or sociological (beneficiary = dependent person) ones etc. which may induce assumptions about the relationship between the two parties. In our case, we use mostly the term of beneficiaries who are actors receiving services to support the inception, the development or the dissemination of their innovative initiative.

1.4. Data collection

We have collected two main types of data. Firstly, we made a review of grey and scientific literature on cocoa quality associated with a collect of secondary data on cocoa production and quality into national and FAOSTAT databases. The second type of that are primary data collected through semi-directive interviews of services providers and beneficiaries of services. For the service provider, we use a purposing sampling approach based on the typology of providers previously identify in the literature. For the beneficiaries, we identify them through snowballing approach starting from information on the web and information coming from providers.

2. Quality as an innovation for Cameroonian cocoa

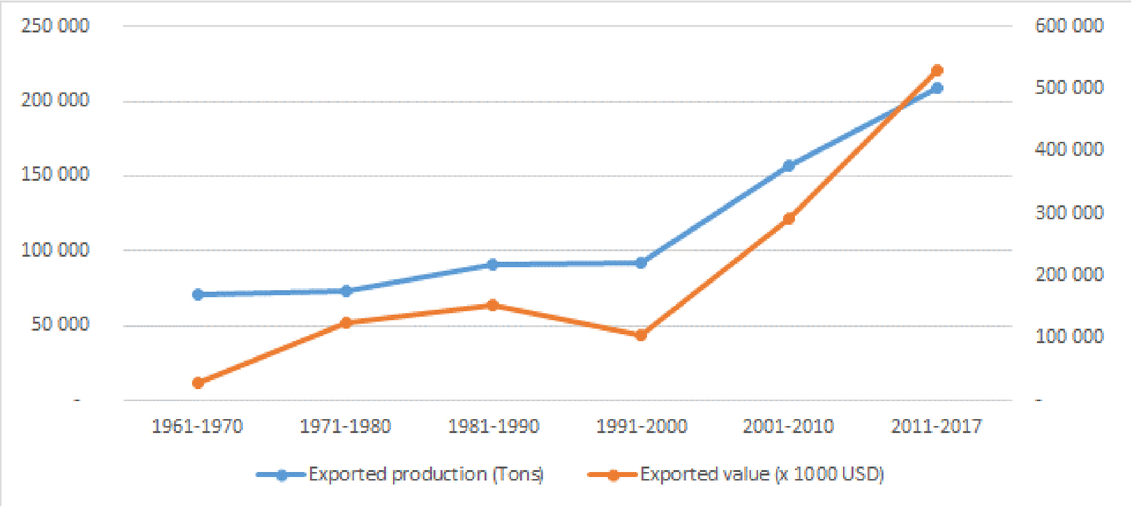
2.1. Liberalisation and jeopardization of cocoa quality

In Cameroon, the cocoa and coffee sectors (robusta and arabica) were closely controlled by the State until 1991 through the National Commodity Marketing Board (ONCPB), the Cocoa Development Corporation (SODECAO), large "parastatal" Agricultural Cooperative Unions (UCA) and "notable farmers" (Fongang Fouepe 2008). Following the fall in world cocoa prices in the late 1980s, the year 1993 marked the effective start of the liberalisation of these sectors with the abolition of the price stabilisation system (Alary 1996). This liberalisation has deeply changed the economic environment, particularly for small producers (Janin 1999). Laven et al. (2016) explained that market reforms have had an impact on price mechanisms and price development in different ways. Firstly, the price stabilization mechanism was abandoned which initially resulted in an increase of farm-gate price. In parallel, it results subsequently to an increase in price fluctuations. Secondly, Laven et al. (2016) noted the loss in farm-gate quality and reliability affected price development and the reputation of Cameroonian cocoa. Thirdly, export become dominated by a small number of foreign firms, creating a situation of oligopsony were exporters set the quality standards and the price, using the world market price as a benchmark. Fourthly, Coxers who informal and non-professionalized intermediate buyers have emerged. Coxers often operate in areas where it is difficult for famers to transport the cocoa themselves. They are more interested in quick availability of cocoa than quality issues (Tollens and Gilbert 2003). They generally work on behalf of Licenced Buying Agents (LBA) who are buyers committed by exporters. Fifthly, farmers find themselves in a weak bargaining position vis-à-vis of coaxers and LBA, which are the both main market channels they use a part of the Farmer Organizations. High quality cocoa is highly related to both the fermentation and drying processes. In fact Cocoa *quality* is used the broadest sense including flavour, purity and physical characteristics that have a direct bearing on manufacturing performance. The Model Ordinance of the International Cocoa Standards defines that cocoa of merchantable quality must be*: "(a) Fermented, thoroughly dry, free from smoky beans, free from abnormal or foreign odours and free from any evidence of adulteration. (b)Reasonably uniform in size, reasonably free from broken beans, fragments and pieces of shell, and be virtually free from foreign matter".* Quality issues are also related to safety with the absence of substance such Hydrocarbures aromatiques polycycliques (HAP) which can be detected when coco have been drying on the ground on bitumen road. Based on these definitions no matter what the genetic origin, the flavour potential of each marketed fine or flavour and bulk variety can only be expressed by appropriate and adequate post-harvest processing. These principles are true for whatever germplasm is being processed.

2.2. Improving quality as future strategy for Cameroonian cocoa production

Cocoa production in Cameroon is 85% to export (ONCC, 2018). The cocoa production is a central crop for Cameroon. It represents a exported production of more than 200,000 tons and an entry of currency of more than half billion of USD per year (Figure 2).

Figure 2. Evolution of production and value of cocoa exported from Cameroon



Source: Compiled from FAOSTAT

The Cameroonian National Cocoa a Coffee Board, which governs the quality of cocoa traded globally, grades cocoa as I, II, or substandard. All cocoa traded must be thoroughly dry and free from foreign matter. The three grades are based on percentage of moldy and otherwise defective beans. Cocoa is supposed to be classified "Grade I" if the number of beans which deviate by more than one third from the average weight of the beans, is not higher than 20 %, a maximum of 6 percent of the beans having mold, a maximum of 8 % of the beans is slate-grey, and a maximum of 6 % of the beans having any other deficiencies. For Grade II cocoa, the maximum percentage for mold is 8 %, for slate-grey beans is 15 % and the maximum of any other deficiencies is 12 % (REPUBLIC OF CAMEROON 2005)

In the periods from 2014 to 2017, almost 98 % of the cocoa exported is in grade 2 (Table 3). Our interviews revealed that this do not means that all cocoa produce in Cameroon is in grade 2. Sometimes, as there are no real differentiation of channels, cocoa in grade 1 are mixing with cocoa in grade 2 and thus are evaluate as grade 2.

Table 3: Evolution of exported cocoa quality from 2014 to 2017

Periods	Grade 1	Grade 2	Non-Standard	Non-Compliant	Broken cocoa beans
2014/15	0,50%	97,42%	1,78%	0,11%	0,18%
2015/16	0,28%	98,23%	0,54%	0,70%	0,24%
2016/17	0,91%	97,59%	0,89%	0,06%	0,59%

Source: ONCC (2018)

Improving quality of cocoa is strategic for Cameroon cocoa for various reasons. Firstly, the global convergence to standardisation of cocoa offer will increase the pressures on the cocoa price on international markets. As cocoa market is liberalised in Cameroon this situation may directly affect cocoa farmers. Quality, *terroir,* and sustainability will be the criteria for differentiation within the global cocoa market. Secondly, the increasing demand for cocoa quality and sustainability from consumers and lobbies. The latter increase the pressure on the cocoa industry to buy sustainable and quality cocoa. This situation conducts to prioritize cocoa with respect to environment (zero deforestation) and using good agricultural and postharvest practices as certified cocoa. With a cocoa production mainly based on agroforestry system (Jagoret et al. 2018), Cameroon has a comparative advantage to build on that for developing high quality and sustainable cocoa production, even with a terroir approach. The production of quality cocoa is an opportunity for Cameroonian cocoa farming and in this sense the breeding ground for the development of innovative initiatives that must be supported.

3. Cameroon cocoa innovation sub-system: providers, services, institutional environment and demand dynamics

3.1. Diversity of service providers

A diversity of actors intervenes actually in the support of innovation in cocoa value chain. This mapping of providers in table 4, is not exhaustive as we use purposive sampling approach, but allow to appreciate the diversity of providers with cocoa innovation system. The mapping also brought to light the existence of a new category of providers, which are international organizations, involved into research or cooperation fields. Additionally, we note the nature of informal services providers is different with the one met in the literature. In our case, they are represented by informal actor of the value chain (coaxers).

Table 4. Providers involved into cocoa innovation system

Category of actors	Name of organisations	Acronym
Public organisations	National cocoa and coffee board	ONCC
	Cocoa Development Corporation	SODECAO
	Institute of Agricultural Research for Development	IRAD
	Ministry of Agriculture and Rural Development	MINADER
	Cocoa and Coffee Development Fund	FODECC
Private organisations (exporters)	NEALICO	NEALICO
	TELCAR COCOA	TELCAR COCOA
	United Trading International	UTI
	AMS	AMS
	Entreprise AGRIBUSSINESS S.A	AGRIBUSSINESS S.A
Third sector farmer-based organisations	Cooperative Society of Mefou et Akono Cocoa Producers	SOCAMAK
	Interprofessional Council for Cocoa and Coffee	CICC
	Cooperative Society of Nyong and So'o Cocoa Producers	SOCOPROCAON
Third sector from civil society-based organisations	Rainforest Alliance/Tropical Forest	RA
Informal service providers	Coaxeurs	//
	International Institut of Tropical Agriculture	IITA

International research and development organisations	World agroforestery Center	Icraf
	Netherlands Development Organization	SNV
	Deutsche Gesellschaft für Internationale Zusammenarbeit	GIZ

Source: Results of field work

3.2. Recommitment of the State concomitant with the emergence of new actors

In Southern countries, different actors such as Farmers' Organisations (FO), input suppliers, public and private institutions etc. can provide services (Faure et al. 2011). In parallel with the liberalisation process, the Cameroonian State is encouraging the establishment of Farmers' Organisations (FO) based on the legislative reforms of 1990 and 1992 relating to associations, cooperative societies and Joint Initiative Groups (GIC) (Fongang Fouepe 2010). These include services such as input supply, production financing, producer training and product marketing (Fongang Fouepe 2010). The real capacity of FO to provide these services is not effective. This situation contributes to the emergence of coaxers who facilitate accessibility to financial and material resources to farmers. Since the beginning of 2010', we note a recommitment of state on cocoa production support through the programme of revitalisation of cocoa value chain (PRDFCC) (REPUBLIC OF CAMEROON 2014) and the development of a specific fund named FODECC (*Cocoa and Coffee Development Fund*) to implement projects such as the PAGQ2C (*Projet d'Appui à la Gestion de la Qualité dans la production du Cacao et des Cafés*). This project aims at enhancing the quality of cocoa through improvement of agricultural practices. Nevertheless, according to Laven et al. (2016) estimations in Cameroon less than 20% of the farmers is reached by public sector services (primarily extensions and training). These are generally the farmers that are close to the administrative units where governmental support is supplied. In parallel, we note the development of the role of the private sector particularly exporters into supporting cocoa value chain. According to Laven et al. (2016) around 30% of farmers are reached by services from the private sector (like credit, inputs and training). In addition, the ONCC has a department in charge of Marketing and Quality Control (DCCQ). It carries out activities such as packaging control, quality analysis, certification and standardization of raw products. Tableau 5 shows a qualitative estimation of the involvement of the services providers in the various type of services. Capacity building and advisory are the main services provided. Services of Knowledge production, demand articulation and institutional support for niches are less developed. The intensity of service provided doesn't reflect the effective accessibility for potential beneficiaries.

Table 5. Intensity of service provided per category of providers

Type of services / Type of providers	Knowledge	Advisory	Demand articulation	Networking	Capacity building	Resource access	Institutional support
Public organisations	++	+++	+	+++	+++	+++	+++
Private organisations	0	++	+++	++	+++	+++	+

(exporters)							
Third sector farmer-based organisations	+	+++	++	+	+++	++	++
Third sector civil society-based Organisations	0	++	++	++	+++	++	+
Informal service providers	0	+		0	++	+++	0
International research and development organisations	+++	++		+	+++	+	+

Source: Results on field work

+++: Service provided as primary activity

++: Service provided as secondary activity

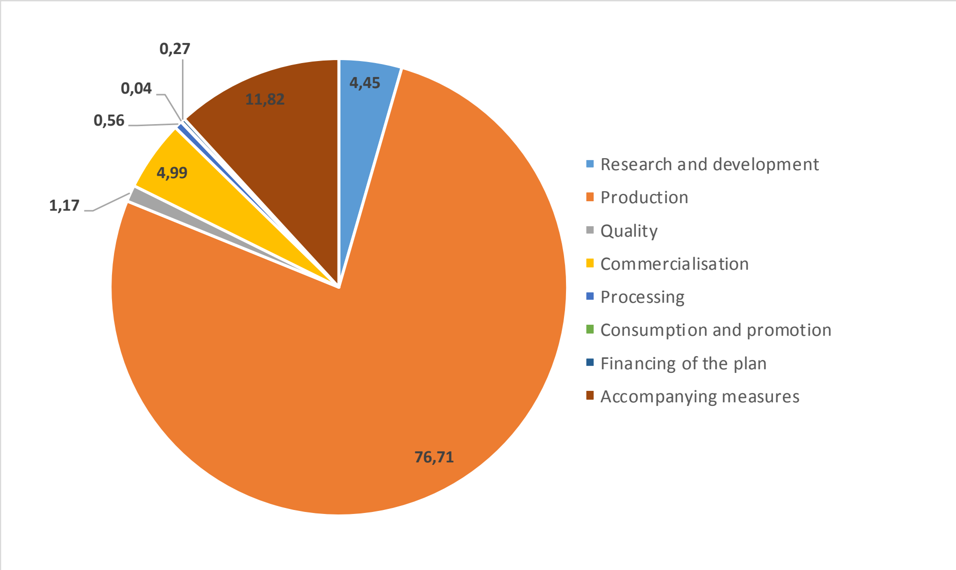
+: Service provided occasionally

0: Service not provided at all

3.3. A national strategy mainly oriented towards cocoa production

Through the plan for the revitalization of the development for the cocoa value chain 2015-2020 (REPUBLIC OF CAMEROON 2014), Cameroon government puts in place various programmes to support cocoa value chain. The PRDFCC plans interventions in: research and development, at the production level, regarding the quality of the product and in the commercialisation. In order to increase competitiveness of Cameroonian cocoa, it is envisaged to improve the quantity (up to 600,000 tons by 2020) and quality of the cocoa predominantly through the encouragement of the use of the Good Agricultural Practices (GAP). We identify that approximately 77 % of the budget are intended to improve the production practices, for which a major emphasis on improving the productivity and the volumes of cocoa produced as well as post-harvest practices. The other major interventions focus on making more easily available the necessary inputs to the producers, improve the organisation of the market and promote the demand for Cameroonian cocoa in the country and abroad. The amount of the budget clearly identified to support quality is less than 2%.

Figure 3. Planned budget for PRDFCC



Source: REPUBLIC OF CAMEROON (2014)

3.4. Emergence of scattered niche innovation based on improved cocoa quality

In the meantime, we identify the existence of scattered niche innovations based on cocoa quality and sustainability improvement. We observe four types of dynamics mainly driven by service providers. These dynamics of innovation service provision benefit directly to farmers and FO:

(1) Dynamics driven by certification agencies as Rainforest alliance with their partner the local NGO Tropical Forest. This agency is involved in the development of certified cocoa. Certified cocoa represents less than 3% of the cocoa produced in 2012 (Potts et al. 2017).

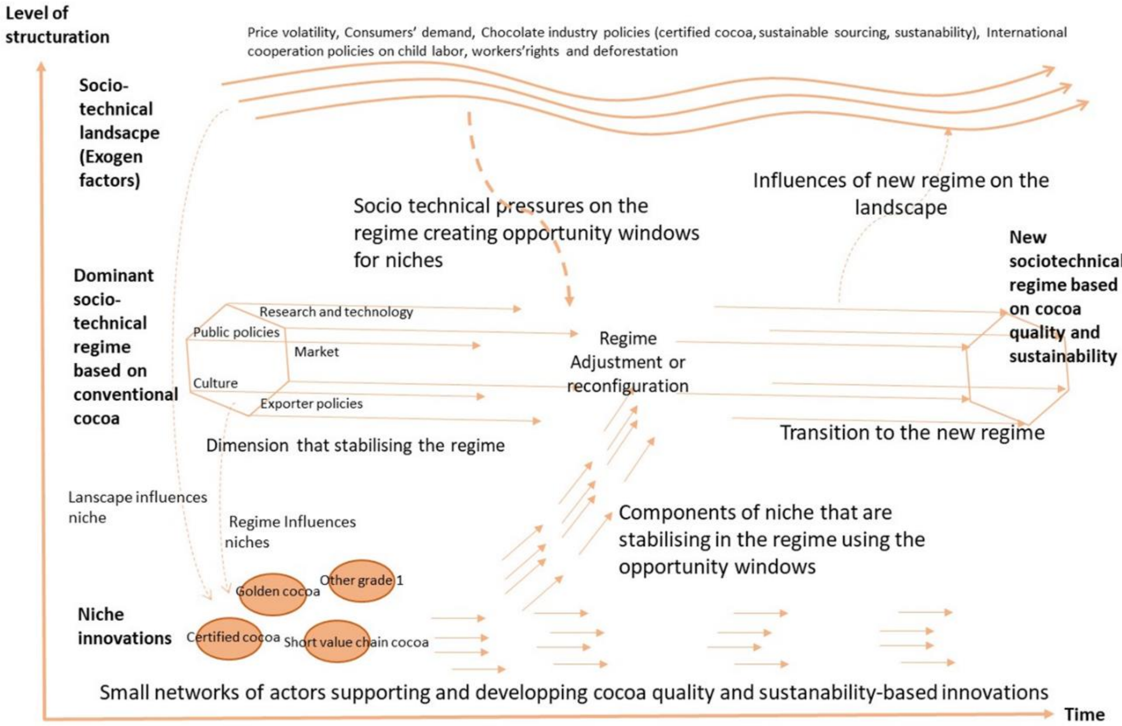
(2) Dynamics driven by national and international development agencies. This dynamic is mainly driven by GIZ and SNV which are deeply involved into development of what they called “Cameroon Golden Cocoa”.

(3) Dynamics driven by FO such as CONAPROCAM initiative, which aims at developing direct market channels with foreign chocolate factories, which are looking for particular flavor.

(4) Dynamics driven by partnership between private and Third sector such as the partnership between Telcar Cacao and CICC to implement Centers of Excellence within which the quality of post-harvest produced cocoa is measured. A measure whereby premium of excellence are offered to the most promising farmers in order to encourage them and encourage the other ones to produce good quality cocoa. This initiative mainly target young cocoa farmers.

These various dynamics are organized as small, scattered and independent networks driven by various actors. These innovative initiatives tend to multiply but they remain at the niche level. The predominant question here is how the quality can be improved on a large scale.

Figure 4. Towards a transition to a cocoa quality and sustainability dominant regime



Source: Adapted from Geels and Schot (2007) and Nuijten et al. (2013)

4. Discussion: what are the main challenges for cocoa quality?

4.1. Embeddedness of cocoa innovation services into intensive production models

Capacity building on good agricultural practices for production are the most provided services. The main beneficiaries of these services are both FO and individual farmers. In almost all the cases, they do not apply to gain access to services. These services are mainly based on intensive models of cocoa production, which aims at increasing yield. These models seems inappropriate for smallholders due to cocoa price volatility and inputs supply difficulties (Jagoret et al. 2018). However farmgate quality getting lower due to pressure of coxers on price negotiation. One of the effects of liberalisation is that some processing functions previously undertaken by farmers are taken illegally by intermediaries (Tollens and Gilbert 2003, Jagoret et al. 2018). These results bring out reflections on the consistency between the actual offer of innovation support services and the transformations that should be supported to increase cocoa quality. The services delivered are based on models of development, which are not align which the development of cocoa quality and the context of cocoa farmers. The main challenge for cocoa quality development will be the change in the mindsets and policies to orient innovation services in cocoa value chain. The new phase of the PRDFCC for the next five years, which is actually discussed, promised to involve these aspects. Furthermore, some interviewees hinted that the cocoa quality in some areas is better than in other regions, so instead of only focusing on global quality, it may be an option to start by using geographical labels. The latter is one of the actual task force of African organization of Intellectual property for "red cocoa" in the Center Region (OAPI).

4.2. Shifting in processing from farmers to intermediaries

Despite its central position in Cameroonian economics, cocoa is not yet a fully controlled and traceable value chain. Since liberalization, producers have had the opportunity to sell cocoa to any intermediaries who buys it. This raises two main problems. On the one hand in setting the prices granted to producers and on the other hand decrease the capacity for cocoa traceability and quality control. The cocoa beans are sold to intermediate agents who do not necessarily respect the standards on cocoa quality. Quality control was one of the key functions performed by the commodity board (ONPCB) that was abandoned in market reforms of the 1990s. ONCC is actually in charge of the quality control not at the farm-gate but directly at ports. These results lead us to identify ways to professionalize intermediaries of developing the availability of facilities to farmers. We identified five entrepreneurial models of post-harvest activities management: (i) Specialized unit not producing but purchasing cocoa pods to break, ferment and dry; (ii) Unit producing cocoa but purchasing additional pods to complete its production before fermenting and drying; (iii) Producers/cooperatives that make their unit available (rent-out model); (iv) Jointly managed fermentation and drying unit (associated producers or cooperators) for use restricted to associated producers or cooperators; (v) Autonomous mobile unit providing specialized labor and equipment for fermentation and/or drying. The first two cases are prohibited by Decree No. 2005/1212/PM of 27 April 2005 on the regulation, packaging and marketing of cocoa beans, but these practices are still ongoing (REPUBLIC OF CAMEROON 2005). The third and fourth entrepreneurial models are close to those practiced by the Centre's cooperatives with processing units. The fifth model, although observed for other crops such as cassava, has not yet been observed in cocoa in Cameroon. These various models need underline research investigations to determine their efficiency regarding farmer capacity of price negotiation and the level of cocoa quality.

4.3. Drivers of transition to quality and sustainability cocoa regime

Quality issues is not only a matter of technical improvement. External factors can play a role into developing innovations to improve quality and sustainability in Cameroonian agriculture (Bayiha et al. 2019) . Various external factors play in favor of the development of cocoa quality in Cameroun. Figure 4 show the actual situation of the high quality and sustainability cocoa niches regarding the whole dominant regime (Geels and Schot 2007, Bayiha et al. 2019). These analyses based on transition approach framework raised various challenges. Firstly, the need for an exhaustive inventory of the innovative initiatives based on cocoa quality and sustainability. This inventory will permit to better analysis the strength and weakness of those initiatives and their scalability. Secondly, the need to improve and adapt the service offer particularly around the production of knowledge to improve cocoa quality and sustainability, the market articulation and services to support niche development and scaling. Consequently, this transformation of the innovation service offer underlines the integration of new services such as coaching more than training (Österle et al. 2016), creativity capacity building (Faure et al. 2019) and funding dedicated to innovation. Thirdly, we emphasize the need to develop a specific market channel dedicated to quality and sustainable cocoa so that the Cameroonian cocoa quality and sustainability can be visible abroad.

5. Conclusion

Our results show a multiplicity of actors, both formal and informal, involved in provision of cocoa quality and sustainability support service. A particularity of the sub-system is the role played by international research and development organizations, which are involved into providing various services at small scale. Globally, various services are provided: access to resources, capacity building, and access to market, networking, advice and agricultural information. A majority of providers declares that they are involved into building the capacity of cocoa farmers and fewer are involved into production of knowledge on quality, access to the market and scaling of niche market. Even, various external factors play as driver towards cocoa quality production, at national level some challenge are remaining. The first challenge is related to productive model in with the cocoa innovation sub-system is embedded; the second challenge is consequently the need to transform and adapt the offer of service. The last challenge identify is related to the capacity to build on innovative initiatives which already exist in order to develop strategy of research and development toward a quality cocoa regime.

Acknowledgements

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REGIONAL AND SUB-SYSTEM SPECIALISATION OF INNOVATION SUPPORT SERVICES PROVIDED IN MADAGASCAR: WHAT KIND OF IMPACT CAN BE EXPECTED FOR FARMERS?

Narilala Randrianarison[a], Sarah Audouin[b], Hycenth Tim Ndah[d], Edson Samuel Noharinjanahary[a], Patrick Dugué[c], Syndhia Mathé[c, e], Harilala Andriamaniraka[a], Tovo Ratsimbazafy[f], Andriamparany Ranoasy[f], Andrianjafy Rasoanindrainy[g]

[a] University of Antananarivo, Ecole Supérieure des Sciences Agronomiques (ESSA), Madagascar
[b] CIRAD, UMR Innovation, BP 319, Antsirabe 110, Madagascar
[c] UMR Innovation, Univ Montpellier, CIRAD, INRA, Montpellier SupAgro, Montpellier, France
[d] University of Hohenheim, Institute of Social Sciences in Agriculture, Division of Rural Sociology, Germany
[e] IITA, PO Box 2008, Yaoundé, Cameroun
fFIkambanana FAmpivoarana ny TAntsaha (FIFATA)
[g] Forum sur le Conseil Agricole (FCA), Antananarivo, Madagascar

Abstract: Agricultural innovation is acknowledged as a driver for rural development, particularly regarding southern countries situations, where agricultural sector is the main activity for rural population. The SERVInnov project aims at strengthening innovation support providers' (ISP) capacities to provide efficient and relevant services to innovators to enable them to successfully overcome problems and improve their livelihoods. This communication presents empirical results from Madagascar, by mobilizing AKIS and ISS frameworks. It focuses on organizational and spatial diversity of services provided to innovators. We studied 5 agricultural innovation subsystems (IsubS), namely staple food, exportation crop, organic farming, poultry farming, and digital agriculture. We selected 4 administrative regions, localized in the center highland area of Madagascar, encompassing similar biophysical conditions but with different cropping systems and economic situations: Itasy, Vakinankaratra, Amoroman'i, Analamanga. The method consisted on ISP and services characterization. Then, we identify trends regarding any specialization or homogenization among ISP, ISubS and spatial units. Results show that services provided are specific to IsubS, and rely on several specialized ISP. For example, exportation crops IsubS are mainly composed by market-oriented services, through support to farmers organisations, tracking of food products, contract farming and are mainly provided by private organisations. Staple food and organic farming IsubS are dominated by technical advices provision through training and demonstration plots, mainly provided by public organisations, funded by international donors, whereas poultry farming IsubS focuses on access to resource like inputs, and equipment. Digital agriculture IsubS is a really recent sector, hence services are mainly related to advisory and information sharing through mobile phone, currently provided by private organisations but also by few research centers. Regarding spatial allocation of ISP, exportation and poultry IsubS are mainly localised in regions closed to the capital. Staple food IsubS is mainly concentrated in Vakinankaratra region thanks to its high diversity of staple crops. ISP in organic farming IsubS intervene in specific regions, illustrating an implicit spatial distribution strategy. These results, raise concerns about real efficiency regarding services relevant and able to reach innovators' needs. On one hand, services specialization according to IsubS hinder systemic approach of farming-systems, whereas household's resilience in highland area of Madagascar relies on diversification of farming activities. Then, spatial distribution of services and ISP may imply that provision of services are unequally accessible for farmers, and through different approaches, values and tools.

SUPPORTING AGRICULTURAL AND AGRI-FOOD INNOVATIONS FOR STAPLE FOOD PRODUCTION IN CAMEROON: PLURALISM OF ORGANIZATIONS, DUPLICITY AND DISCONTINUITY OF SERVICES

Rodrigue Kamga[a], Guillaume Hensel Fongang Fouepe[a], Syndhia Mathé[bcd], Sarah Crestin-Billet[e], Ludovic Temple[f], Andrea Knierim[e]

[a] University of Dschang, Dschang, Cameroon
[b] INNOVATION, Univ Montpellier, CIRAD, INRA, Montpellier SupAgro, Montpellier, France
[c] CIRAD, UMR INNOVATION, Yaoundé, Cameroun
[d] International Institute of Tropical Agriculture (IITA), Yaoundé, Cameroun
[e] University of Hohenheim, Stuttgart, Germany
[f] CIRAD, UMR Innovation, Montpellier, France

Abstract

The innovation systems approach is an analytical framework that is increasingly used to address agricultural innovation support services (ISSs). In the staple food production sector of Cameroon, a plurality of innovation support service providers (ISPs) co-exist, but ISSs are largely delivered within the framework of agricultural and rural development projects or programs. This paper aims to assess the impact of such governance mode on ISS delivery. Using a mixed research approach, empirical data have been collected focusing on the cassava innovation sub-sector in Southern region of Cameroon. ISPs at the local, regional and national levels (n=11) were first identified through literature review. Semi-structured questionnaires were administered to this first sample in order to create an ISP and projects database. A second semi-structured questionnaire was then administered to an enlarged group of ISP respondents (n=27) in order to characterize ISPs and ISSs, as well as to identify and measure the interactions among ISPs. Results indicate that public international and national ISPs dominate the system (high number of projects, ISSs and interactions with other ISPs), and that this leads to duplicity of certain types of services. The private sector and Farmer-Based Organizations (FBOs) are also present and offer rather complementary ISSs, but their number is comparatively lower. The lack of intermediary services to coordinate the overall ISS system, the rather low density level of ISP interactions and their informal quality give the impression of a fragmented ISS system. But, the interactions among ISPs are actually essentially very uneven. Although international public ISPs already interact well with FBOs, partnership strategies towards national public ISPs still need to be implemented. In turn, national public ISPs should also strengthen their links with these FBOs. Overall, ISSs delivered by national and international public ISPs, as well as by the FBO umbrella organization (PROPAC) are mainly funded on project bases, which raises the risk of service discontinuity. Multi-actor partnerships and innovative mixed funding strategies need to be supported to improve the efficacy and the quality of ISSs delivery.

Introduction

Agriculture is the backbone of Cameroon's productive sector representing 22.8% of the Gross National Product and employing 65% of the country's active population. Agriculture contributes to the national food security and sovereignty, to foreign exchange earnings and produces raw materials for the industrial sector (Mouafor et al., 2016).

In Cameroon, staple crop production employs more than 50% of the active population and contributes about 64% of the agricultural GDP (République du Cameroun, 2010). Staple crops include a wide variety of agricultural products: roots and tubers (cassava, cocoyam, potato, yam, etc.), cereals (maize, paddy rice, millet and sorghum, etc.), oilseeds (groundnuts, cotton seed, etc.), fruits and vegetables such as bananas, plantains, pineapples, papaya, but also sausages, avocados, dried vegetables, spices, leafy vegetables, ornamental plants and flowers, etc. (Kidd et al., 2000; Achancho, 2013). Staple crops are less demanding in terms of investment in inputs than export crops, as such, staple crops ensure food security through self-consumption, the supply of local markets and the generation of income for agricultural households and mainly women (Mouafor et al., 2016). Despite this diversity of products and its contribution to the country's food and nutritional security, agricultural yields remain low compared to their agronomic potential (Kwa & Temple, 2019). Production techniques remain very manual, using few inputs except for some very intensive forms of production such as banana production for exports. The perishability of products and the failure of infrastructural logistics also generate heavy post-harvest losses. Other constraints include weak organization of actors within the food chains, embryonic processing and marketing (FAO, 2018; Ebela, 2017).

The importance of staple food for Cameroon has been taken into account in agricultural and food policies (Ebela, 2017; Fongang, 2008). In particular, the Food Crop Development Mission (MIDEVIV) created in 1981 as part of a national plan entrusted by the State mainly aimed at supporting the production and marketing, as well as the supply of improved seeds to farmers. This orientation has been reaffirmed in the context of the New Agricultural Policy, formulated after the economic crisis that led the State to withdraw from some of its providential functions. The formulation of the Development Strategy of the Rural Sector in 2006 and its revision within the framework of the Strategic Document for Growth and Employment in 2010, which continue to structure the current agricultural policy guidelines take into account the food production sector, but remain quite generic and focused on productivity objectives. Moreover, the recent public policies in support to agricultural innovations (Ntsama, 2009) remain guided by the development model of the 1960s and 1970s Green Revolution in Asia, that is, that of high capital-intensive, input-intensive and highly productive agriculture (Bayiha et al., 2019). This is however in contradiction with the international guidelines, such as the renewed MDGs edited by the Food and Agriculture Organization (FAO, 2020; Dury et al., 2019) which encourage a renewal of conventional agricultural intensification policies by integrating sustainability aspects such as environmental resource management and social inclusion in order to reduce unequal access to food resources.

Agricultural innovations in Cameroon have traditionally followed a “diffusionist” scheme in which innovations - mostly technical such as new varieties, cultural practices and technical itineraries - originate from national public research organizations and are then disseminated to farmers by agricultural extension services through producer organizations (IRAD, 2013). The disengagement of the state from its public functions between 1980 and 2000 has however stimulated the emergence of a myriad of new actors (private organizations, international and national NGOs, NGO networks, inter-professional organizations, farmer organizations (FO) and their grouping). Through specific development projects and programs, these providers are engaged in a wide range of activities such as: distribution of seeds and improved seedlings to farmers, agricultural marketing, rural animation, organization of farmers involved in agricultural chains, technical experimentation, supply of other agricultural inputs, technical advice, agricultural financing, etc. (Temple et al., 2019). These activities can be defined as innovation support services (ISSs). "*An innovation support service is intangible, and involves one or more suppliers and one or more beneficiaries in activities in which they interact to address a more or less explicit request arising from a problematic situation and formulated by the beneficiaries and to co-produce the services aimed at solving the problem. Interactions aim to achieve one or more beneficiary objectives based on the desire to strengthen an innovation process, i.e. to promote technical and social design, enable ownership and use of innovations, facilitate access to resources, help transform the environment and build capacity for innovation*" (Mathé et al., 2016). The consolidation of farmer organizations has received a particular attention from the State that wishes to precisely invest in projects/programs aiming at consolidating farmer organizations and improve food security (Ntsama, 2009).

However, despite the implementation of these strategies and the emergence of projects/programs to increase the quantities produced of certain food crops (cassava, maize and plantain), it must be noted that the volume of the main food crops has remained almost stagnant (Achancho, 2013) or that at least production per agricultural input has slightly increased. This raises questions about the effectiveness of projects/programs as a means of intervention in support to agricultural and agri-food innovations. Project and program-based development interventions can allow a diversity of actors to join forces and thereby contribute to build farmers’ individual and collective problem solving and innovation capacities

(Nagel, 1997). There are however also many examples of partnerships within the framework of projects which have failed to promote and disseminate innovations, in some cases due to a lack of linkages with some local organizations and market actors (Hall, 2006), due to strong network failure blocking the access to external knowledge (Mofakkarul et al., 2013) or due to loose relationships between the actors of a network (Magala et al., 2019), leading to “missed opportunities for collaboration and a limited recombination of knowledge and resources” (Hermans et al., 2015). Projects/programs also constitute a clear risk to the continuity of service provision due to their short time span as it has been observed in other contexts (Martínez-Cruz et al., 2019; Kidd et al., 2000; Faure et al., 2013).

Taking the cassava crop as an illustration of the staple food sub-sector in Cameroon, this paper aims to assess the importance of public project/programs as a mode of ISS delivery. It shall characterize and allow a comparison of the innovation support providers (types of organizations, types of delivered ISS, types of supported innovations and types of funding arrangements) and finally examine their linkages (density of interactions and nature of their relationship). We define “innovation support service provider” (ISP) as any actor (individual or corporate) who offers one or more innovation support services to another actor across the innovation process.

Research methodology

ISPs identification (Phase 1)

The study was conducted within the framework of the SERVInnov project (https://umr-innovation.cirad.fr/projets/servinnov). The Southern region of Cameroon is one of the main staple crop production lowlands area and was thus selected to analyse its Cassava innovation sub-system. Based on a literature review (including grey literature in French), a first sample of 11 ISPs active at the local, regional and national levels were identified (Table 1). A semi-structured questionnaire and face-to-face interviews with these ISPs were then conducted in order to obtain a general understanding of the sub-sector and to identify new ISPs. The interview guide was divided into five sub-sections: overview of cassava’s food chain in Cameroon, agricultural innovations developed in this food chain, ISPs engaged, innovation support system and main constraints encountered by ISPs. The interviews took place in the Southern, Central and Littoral Regions from April 26, 2019 to June 08, 2019.

ISPs and ISSs characterization (Phase 2)

Using the answers from the first phase of data collection and using a snowball sampling technique, a larger sample of ISPs was formed. In total, 27 semi-structured interviews were conducted with representatives from 14 organizations and 5 individuals which we classified into the informal sector, as they supply ISSs outside of any formal institution. These individuals are economic actors who have develop some expertise about cassava. All of them are present and active in the Southern region of Cameroon (Table 1). The questionnaire focused on the ISP typology, the offered ISSs, the main beneficiaries of these services, the funding mechanisms and the interactions of the ISP with other ISPs of the subsystem.

Table 1. Number of conducted interviews among innovation support service providers (ISPs) for each study phase

ISP types	Interviewed ISPs	Phase 1: ISPs identification	Phase 2: ISP and ISS characterisation
National public organizations	MINADER (DRCQ)	2	8
	MINEPAT	1	1
	IRAD	1	1
	IMPM		1
	Agricultural chambers		2

International public organizations	IITA	1	1
	CTA		1
	PRASAC	1	1
Private enterprises	CRIFAT		1
	Rural Investment Credit		1
	People's Finances		1
Farmer-based organizations (FBOs)	PROPAC		1
	CNOP-CAM	1	1
	PIP-CV	1	1
Informal sector	Individuals	3	5
Total		11	27

Interview data analysis

Transcriptions and coding of the qualitative information for the two study phases were done without the use of any software. Quantitative data were processed in EXCEL 2013.

ISPs mapping

A social network analysis of the identified ISPs was conducted with the mean of an actor matrix (Biggs & Matsaert, 2004). When constructing the actor matrix, emphasis was placed on the presence or absence of interactions between ISPs. In this study, interactions between ISPs are defined as any type of contact, formal or informal, between two or more ISPs leading to exchange of information, activities, access to inputs or trade related to cassava. The matrix also included the nature of the linkages: informal collaboration (informal interactions between two or more providers), partnership (interactions between two or more providers which are formalized by a contract), and coopetition (collaborative work among potentially competing ISPs in a way that benefits both of them). This matrix was then used to manually draw the ISP mapping. This was done using EXCEL 2013 from Microsoft Office.

Measure of ISP interactions

Using the actor matrix and based on a methodology from Borgatti et al. (2009), we were able to calculate:

Degree of connection

To have information on the weight of each ISP in the network, we calculated the degree of connection of each ISP. According to Mercklé (2004), the degree of connection of an actor is an indicator of its integration or, on the contrary, of its isolation in the entire network, or an indicator of its centrality. An actor's degree of connection is indicated by the number of non-zero entries (numerical sum) that are recorded in an actor's row or column of an actor matrix, in other words, it is its total number of linkages to other ISPs.

Percentage of interactions

To know the total number of interactions per ISP within the system, we calculated the percentage of interactions between ISPs.

$Ni= ((n \times n)-n)/2$, where Ni: maximum number of possible interactions and n: number of ISPs. The totality of the 15 ISPs was used to calculate the maximum number of possible interactions between ISPs in the cassava innovation subsystem.

Density of network

To know the number of ISPs who are actually linked to others within the system, we calculated the density (D) of the ISP network.

D = λ/ (N (N-λ)/2) where λ: total number of linkages and N is the number of ISPs in the network.

Results

The results of the data collection and data analysis are presented hereafter. First of all, a general characterisation of ISPs (governance type, administrative scale of activity) is provided. Secondly, the ISSs are characterised in terms of their type of service and level of importance for the ISPs, as well as in terms of their main funding source (project- or non-project-funded). The different funding arrangements for each type of ISS are then also provided. Finally, the mapping and measure of the interactions between ISPs are presented and the nature of the collaboration arrangements is identified.

ISPs characterization

The cassava innovation system is characterized by the existence of a plurality of ISPs (

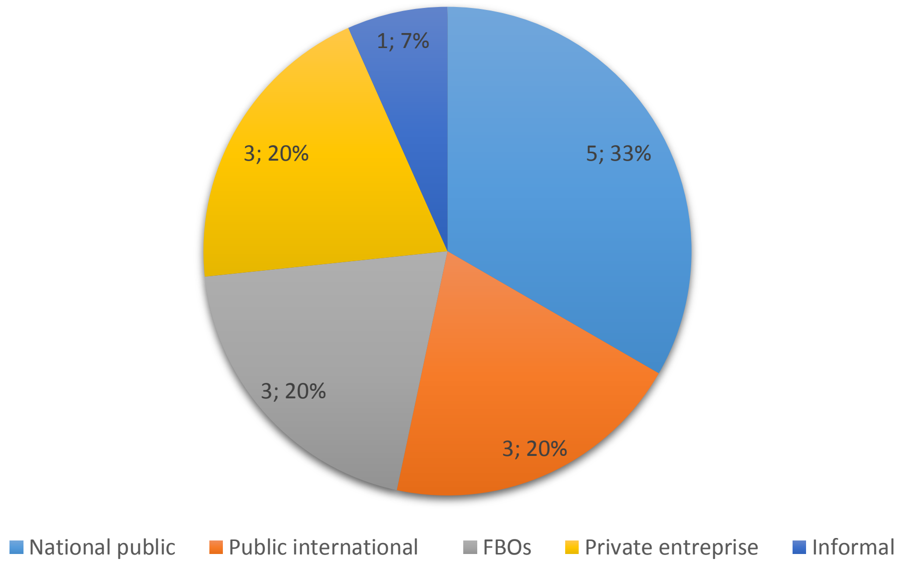


Figure *1*). On the basis of their status, objectives and source of funding, they can be classified into five categories: national public, international public, Farmer-Based Organization (FBOs), private enterprises, and informal (independent individuals). Based on our investigation, the most numerous ISPs in the cassava sector are national public organizations (MINADER, MINEPAT, IRAD, IMPM, and the Chamber of Agriculture). International public organizations (IITA, CTA, PRASAC), FBOs (PROPAC, PIP-CV, CNOP-CAM) and private enterprises (CRIFAT, Rural investement credit and People's finances) each count three organizations and the informal sector counts one individual.

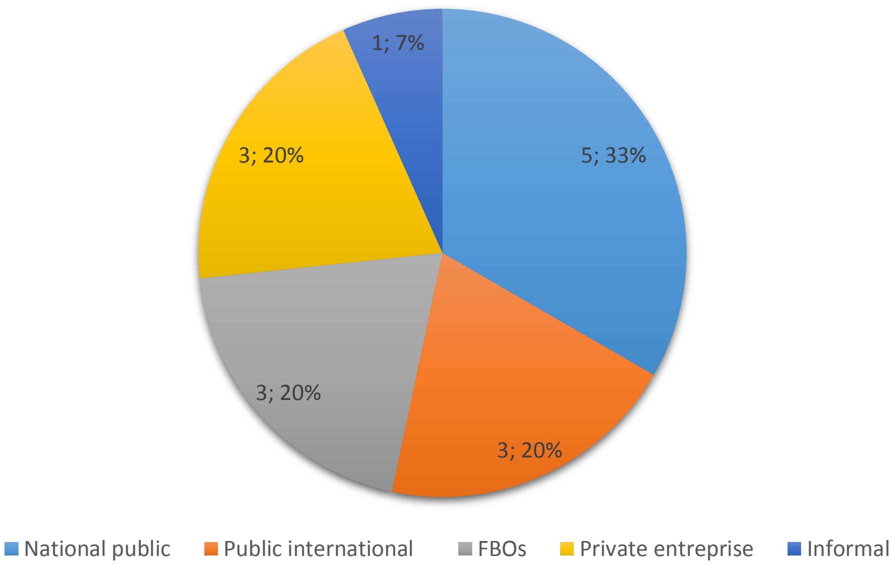


Figure 1. Distribution (absolute numbers) of innovation support service providers (ISPs) types in the cassava subsector in the Southern region of Cameroon

ISSs characterization

Seven categories of innovation support services (ISSs) have been identified within the cassava innovation subsystem (

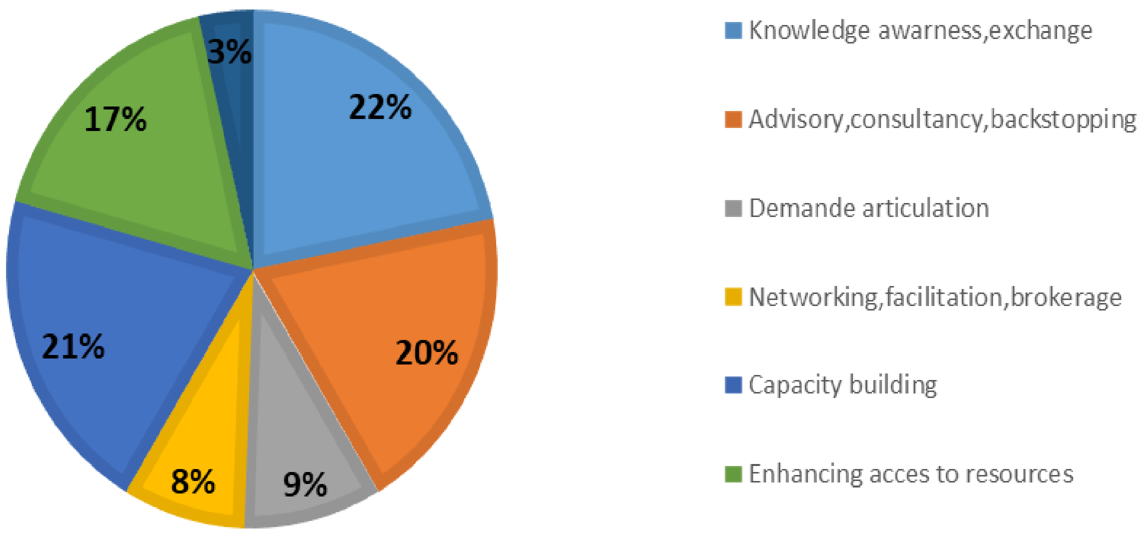


Figure 2). Knowledge awareness and exchange (22%) is the main provided service followed by capacity building (21%), advisory, consultancy and backstopping (20%), enhancing access to resources (17%) and much less provided are demand articulation (9%), networking, facilitation and brokerage (8%) and institutional support for niche innovation, and scaling (3%).

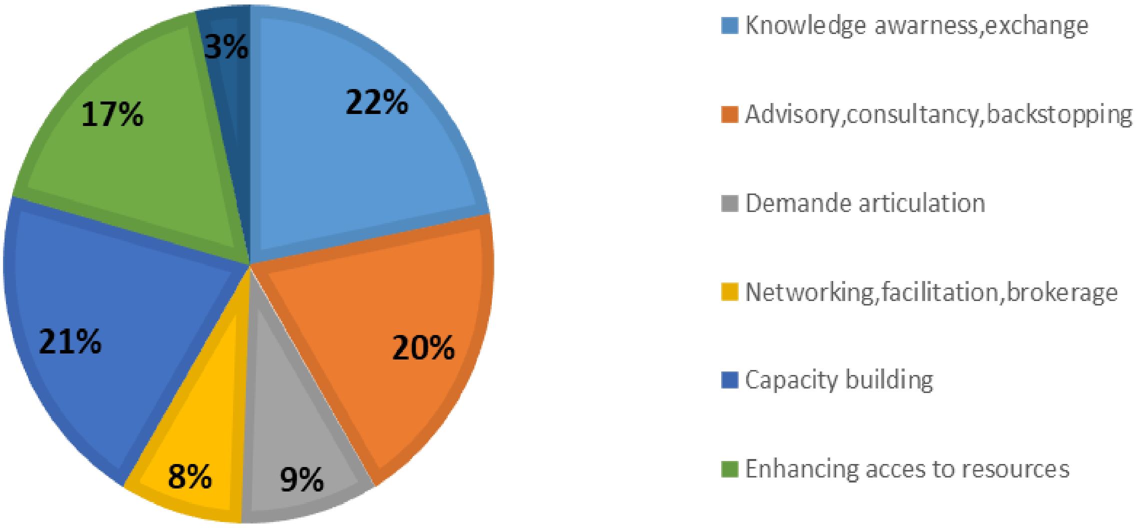


Figure 2. Distribution (%) of innovation support services (ISS) types in the cassava subsector in the Southern region of Cameroon

ISSs / ISPs			KNOWL. (Knowledge awareness, exchange)	ADVIS. (advisory, consultancy, backstopping)	MARKET. (demand articulation)	NETWORK (networking, facilitation, brokerage)	TRAIN. (capacity building)	RESS. (enhancing access to resources)	INSTIT. (institutional support for niche innov., scaling)
Type	**Name**	**Project**							
International public	IITA		++	++	O	O	++	+	+
	CTA	Manioc 21	++	+	+	++	++	+	O
	PRASAC		++	+	++	+	++	+	O
Nation. public	IRAD		++	++	O	O	++	+	+
	IMPM		O	O	O	O	O	++	O
	MINADER	DRCQ	++	++	O	O	+	+	++
		PIMDA	++	+	+	+	++	++	O
		PADRT	++	++	+	O	O	++	O
		APAPE	++	++	+	+	++	+	O
		PROSAPV	++	++	O	O	++	+	O
		PAPMAV-Q	++	O	O	O	O	O	O
		ACEFA	+	++	+	O	+	++	O
		AFOP	+	++	O	O	++	++	O
		PAIJA	+	++	O	O	++	++	O
	MINEPAT	Agropoles	++	+	+	+	++	++	O
	Chamb. of Agriculture	Pionnier	++	++	+	+	++	+	O
		CIP	++	+	O	O	++	O	++

Private Entr.	CRIFAT	YA-Manioc	O	++	**++**	O	**++**	**+**	O
	Rural inv. credit		O	O	O	O	O	++	O
	People's finances		O	O	O	O	O	++	O
FBOs	PROPAC		**++**	**++**	**+**	**+**	**++**	**+**	O
	PIP-CV		++	+	**++**	++	+	+	O
	CNOP-CAM		++	+	+	++	**++**	+	O
Inform.	Individuals		++	++	O	+	++	O	O

++: Main service provided

+: Service provided of secondary importance for the ISPs

++: Main service provided mainly through projects/programs

+: Service provided of secondary importance for the ISPs mainly through projects/programs

O: Service not provided at all

Table 2 Innovation support services (ISSs) provided by innovation support service providers (ISPs) of the Cassava subsector in Southern Cameroon.

Depending on their type, ISPs provide specific ISSs which are either of primary (among the three ISSs that they the most actively provide) or secondary importance to them (Table 2). We further specify whether these services are provided within the framework of projects or programs and whether the share of project funding is the greatest or not in the case of ISS co-funding.

The international public organizations solely supply project-/program-based ISSs. Knowledge dissemination and training prevail (development of and training on local seed varieties, improvement of cropping practices, fight against diseases and rodents, conservation and food products processing). Recent projects (Manioc 21) however entail new types of services aimed at strengthening the entrepreneurship, Marketing, networking and financing capacities of cassava producers and their cooperatives (trainings, development and facilitate access to ICT tools, new marketing linkages and innovative financing schemes). Facilitating access to resources is a secondary activity of all the international public actors. Institutional support is only provided by IITA as an activity of secondary importance.

All the national public service providers – with the exception of IMPM and two projects of the MINADER – deliver ISSs within the framework of projects which largely remain focused on knowledge dissemination, advisory and training. The majority of the national public ISPs are also strongly involved in facilitating farmers' access to resources (e.g. Programme Agropoles from the Chamber of Agriculture, the PIMDA, PADRT, ACEFA, AFOP and PAIJA programs from the MINADER, IMPM). Marketing and networking ISSs are rather secondary activities for those who carry them out (MINADER, MINEPAT and Chamber of Agriculture). Institutional support is only a major activity of two organizations: the Chamber of Agriculture (CIP) and the MINADER (DRCQ). The latter provides, for instance, seed plots certification and the granting of approvals to seed companies.

Private organizations, in contrast, seldom provide services through projects or programmes Only one actor, CRIFAT provides services such as demand articulation, training and access to resources facilitation through the YA-Manioc Project. Moreover, private ISPs are not at all engaged in knowledge dissemination and institutional support. Facilitating access to resources of cassava producers is the main or the secondary activity of private ISPs.

Among FBO's main services are knowledge dissemination (all three FBOs), networking and training (two providers) and advisory (PROVAC, project-funded). The public FBOs consider advisory (PIP-CV, CNOP-CAM), Marketing (PROVAC, CNOP-CAM) and facilitation to access resources (all three) as rather secondary activities to them. Institutional support doesn't count among their activities at all. PROPAC's activities are mostly project-based; whereas the two other interviewed FBOs only fund one of their service types through project (Marketing support and training).

The interviewed individuals support innovative stakeholders with knowledge dissemination, advisory, training and to a lesser extent networking.

Several respondents report a lack of coordination among the actors and duplicity of actions. One member of an FBO ISP explains: "My structure (PIP-CV) has direct partnerships with other ISPs. As far as relationships are concerned, there is no interaction because for the moment everyone is acting on his own. Sometimes they act on the same activity but do not collaborate. An example: CTA came to train the same actors and the same way as PRASAC had already done. We do the same things with the same people and repeat ourselves over and over again." Different projects also focus on the same varietal innovations developed by IRAD and IITA such as: APAPE, PADRT, Pioneer Program, PIDMA and PAPMAV-Q. Indeed, these projects/programs are all involved in the dissemination of the same improved varieties of cassava cuttings (8034 and 96/1414 developed respectively by IRAD and IITA) to women producers located in the same production areas.

ISPs \ ISSs			KNOWL.	ADVIS.	MARKET.	NETWORK.	TRAIN.	RESS.	INSTIT.
Type	Name	Project							
International public	IITA		+	+			+	X	+
	CTA	Manioc 21	+	+	+	+	+	+	
	PRASAC		+	+	+	+	+	+	
National public	IRAD		+	+			+	X	+
	IMPM							O	
	MINADER	DRCQ	O	*			*	O	*
		PIMDA	X	X	X	X	X	X	
		PADRT	X	X	X			X	
		APAPE	X	X	X	X	X	X	
		PROSAPVA	+	+			X	X	
		PAPMAV-Q	+						
		ACEFA	X	X			X	X	
		AFOP	+	+			+	X	
		PAIJA	+	+			+	X	
	MINEPAT	Programme agropole	X	X	X	X	X	X	
	Chamber of Agriculture	Programme pionnier	X	X	X	X	X	X	
		CIP	X	*			X		X

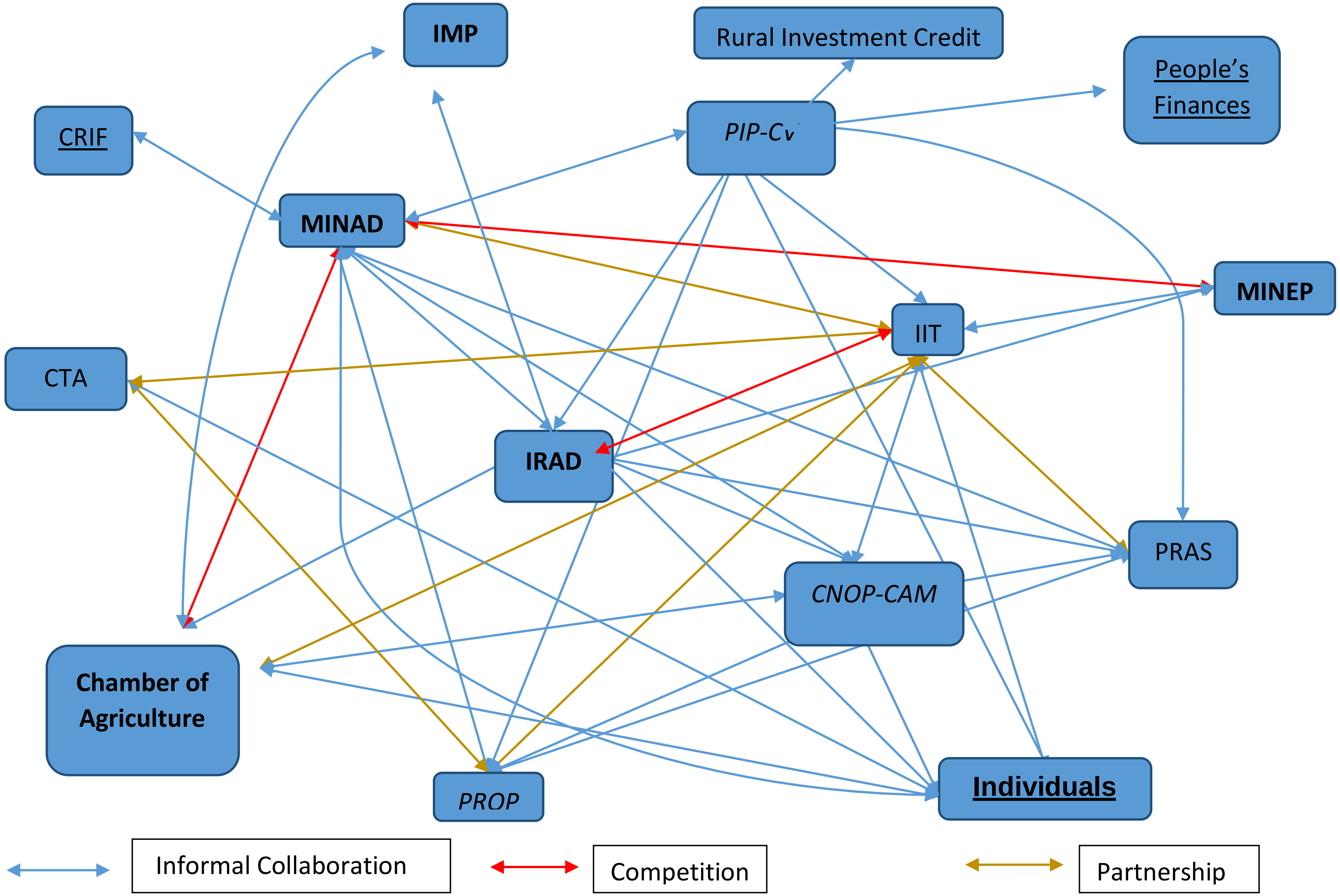
Private Entreprise	CRIFAT	YA-Manioc				*			X						X								
	Rural investement credit																	O					
	People's finances																	O					
FBOs	PROPAC		+			+			+			+			+			+					
	PIP-CV		+	*	X	+	*	X	+	*	X	+	*	X	+	*	X	+	*	X			
	CNOP-CAM		+	*	X	+	*	X	+	*	X	+			+	*	X	+	*	X			
Informal	Individuals		*			*						*			+	*							

+ : Solely Project/Program-funding   * : Solely charged to ISS beneficiaries

O : ISP-Beneficiary co-funding   X : Project-Beneficiary co-funding

Abbreviations of ISS types: **KNOWL**. (Knowledge awareness and exchange), **ADVIS.** (advisory, consultancy, backstopping)**, MARKET.** (demand articulation**), NETWORK.** (networking, facilitation and brokerage**), TRAIN**. (capacity building), **RESS.** (enhancing access to resources)**, INSTIT.** (institutional support for niche innovation, and scaling).

Table 3. Innovation support services (ISSs) funding mechanisms of innovation support service provider (ISPs) in the Cassava subsector of Southern Cameroon.


IMP
Rural Investment Credit
People's Finances
CRIF
PIP-Cv
MINAD
MINEP
IIT
CTA
IRAD
PRAS
CNOP-CAM
Chamber of Agriculture
PROP
Individuals
Informal Collaboration
Competition
Partnership

The funding mechanisms which are used to finance ISSs differ among the various ISP types (Table 3). International public ISPs usually finance the delivered ISSs through project funds as a sole source of funding (16 counts out of 17). Most of the national public ISPs also do so (13 counts), but co-funding with the participation of ISS beneficiaries is even more commonly used (39 counts). The DRCQ, a project of the MINADER utilises alternative modes such as ISP-Beneficiary co-funding (KNOWL., RESS.) or service costs can also entirely be charged to the beneficiairies (ADVIS., TRAIN., INST.). Private enterprises use all types of mechanisms except purely project-funds. Public FBOs use three different types of funding mechanims also within one category of ISS (co-funding by projects and beneficiaries, beneficiary-funding or project-funding). Finally, individuals' ISS charge the beneficiaries (3 counts out of 4) or benefit from project-funding (TRAIN.).

Interactions between ISPs

Nature and degree of connection

As it can be observed on the mapping of interactions (Figure 3), each of the ISPs have at least one informal collaboration with another ISP; this is the main collaboration arrangement. Formalised partnerships happen only among some of the international public ISPs (2 counts), as well as between international and national public ISPs (2 counts) or between the international public ISPs and the Public FBO PROPAC (2 counts). Relationships of coopetition happen among national public ISPs (2 counts) and among national and international public ISPs (IRAD-IITA).

The ISPs interactions mapping also shows the number of interactions of each ISP with other ISPs (Figure 3). Actors who participate in programs have a high number of connections with other ISPs: 9 and 10 connections of the MINADER and IRAD, respectively, 10 connections of the IITA. FBOs are connected to a high number of public ISPs (6-7 connections) and individuals. Only one FBO (PIP-CV) is informally connected to a private actor (the Rural Investment Credit). Private actors seem particularly weakly connected with only one client each. Percentage of interactions and density of network

Our analysis shows that only 38% of interactions (80 interactions) are maintained between ISPs of the cassava subsector, which is relatively low as compared to the maximum number of interactions that could be reached (210 interactions). This result is confirmed by the calculation of a network density indicator which is equal to 0.38, lower than that of an ideal situation (density =1). The relationships to economic actors of the value chain seems to be missing as one interviewee mentioned: "The prospects are not promising because of the lack of real and practical coordination of actions of all stakeholders in the cassava sector towards the main actors, namely farmers, processors, traders and distributors of fresh and processed cassava products" (Y1 - researcher specialized in cassava).

If all types of interactions are taken into consideration, the density of interaction of international ISPs with FBOs is high (78%), medium with national public ISPs (40%) and other international public ISPs (33%). The density of interaction of national public ISPs is high with other ISPs of the same type (70%), medium with FBOs (40%) and very low with individuals (20%) and private actors (7%). The density of interaction of private actors is the highest with FBOs (22%) and FBOs' density of connection with other FBOs is only 50%, 67% with individuals and 11% with private enterprises.

Discussion

Examining the innovation support system of the cassava sub-sector in Southern Cameroon can potentially help identify some hindering aspects to its development. This is at utmost importance given the need to better align innovation objectives with social and environmental challenges, such as food security, rural employment, and inclusiveness.

From our empirical results, it clearly stands out that ISSs are mostly provided within the framework of public projects or programs (13 have been identified) that apparently follow a top-down approach with little coordination among them. The relative high importance of project/programs can be explained by the dominance of international and national public ISPs and by the relative low representation of other actor types. This illustrates the relative low level of privatization of agricultural extensive services as compared with other African countries (Pelon, 2019). As a result, ISSs still mostly consist in knowledge awareness and exchange, advisory and training on technical innovations (e.g. seed varieties) which originate from international and national Research and Development institutions in a top-down manner. This corresponds to the first STI policy frame described by Schot & Steinmueller (2018). Networking, demand articulation and enhancing access to resources which aim at building links and stimulating learning between elements in the systems, and enabling entrepreneurship (Schot & Steinmueller, 2018) are also well represented, but remain rather secondary activities to most of the public ISPs. In contrast, the private sector defines resource enhancement as one of its main or secondary activity. Finally, FBOs are also key actors in terms of organization of women producers and processors. The private and FBO sector thus seem to complement well the public offer, although many types of ISSs are not enough delivered or are missing (e.g. brokerage functions, institutional support).

Taking informal types of collaboration into consideration, we find that the low percentage of interactions (38%) and density of network (0.38) are similar to those of Spielman et al. (2008) obtained in Ethiopia. This result corroborates observations from other authors on the fact that there is a lack of interaction and coordination among actors of the cassava value chain (Njukwe, 2016; Meyo & Liang, 2012).

Moreover, the high degree of connection obtained by some public organizations and FBOs in the system confirms their central role. The private sector comparatively has a very limited network. This is similar to the situation reported in Costa Rica (Coq et al., 2012). More specifically, the ISPs who are involved in projects or programs are the one having the highest number of connections. Nonetheless, the overall coordination of the network is weak since duplication of interventions have been reported, particularly within the framework of projects. This lack of coordination and capacity to co-produce ISSs with beneficiaries and to align various ISSs could be due to a lack of support to social and organizational innovations (Faure et al., 2019) and to the fact that the percentage of interaction of national public ISPs with FBOs is rather low (40%). FBOs also connect poorly among themselves (50% of interactions). However, international public organizations have developed a relatively higher level of interaction with FBOs (78%) which is promising to align R&D with the needs of smallholder farmers. However, the levels of interaction of international public organizations with national public ISPs (40%) and other international ISPs (33%) could be improved in order to limit the duplication of activities and better coordinate the overall network. National public ISPs already connect well together (70%).

Characterizing the nature of these linkages, we also show that most of the interactions are taking place informally.

One limitation of our study, is that it doesn't show the direction and whether the linkages are impacting or not. It might indeed well be the case that some linkages are ordinary with no implications for the innovation process (Biggs & Matsaert, 2004). As a result, it is hard, for instance, to draw conclusions on the role and true influence of FBOs on innovation processes. Given the technological nature of the supported innovations and the apparent dissatisfaction of FBO representatives about the services they receive through projects, we suppose that the relationship between FBOs and public ISPs gives little space for co-construction of ISSs. Our findings on the funding arrangements pursued by each ISP (Table 3) usefully highlight the fact that FBOs have recourse to diverse funding modes – except PROPAC a public umbrella organization for FBOs. This can thus give FBOs a certain degree of autonomy (Coq et al., 2012).

A second limitation of our study is that our sampling of ISPs has been formed thanks to interviews with ISPs at the national level (MINADER, extension services and research institutions). This might explain why no other forms of civil society organizations (e.g. NGOs and "Economic Interest Groups") active in the cassava sector were identified. Another reason given by Temple et al. (2017) could be that the relationships between intermediaries and research institutes in Cameroon are rather interpersonal. A more exhaustive ISP mapping should thus be undertaken by the mean of a structured questionnaire sent to a greater diversity of ISPs.

Conclusion

Our study clearly shows that the cassava innovation system of the Southern region of Cameroon is strongly based on ISPs from the public sector, that comprise the so-called mainstream institutions and their projects/programs-funded ISSs. As a consequence, the traditional agricultural extension services that support technical innovations are largely represented in the system. The civil society and private sectors complement the ISSs offer to a certain degree and make use of some alternative funding mechanisms, but there are not many of them. ISSs are mostly dependent on projects funding which can cause some discontinuity of ISS, although FBOs are able to diversify their funding modes. The network of actors is not very dense, but some ISPs (national and international public organizations, FBOs) are strongly linked to a large diversity of other actor types, especially through projects and through informal collaborations. The lack of coordination among actors is felt by FBOs due to the duplicity of ISSs they benefit from. This can be explained by the low percentage of interaction of national public ISPs with them, as well as by the low level of brokerage services in the system.

To address current social and environmental challenges the capacities of the existing organizations need to be reinforced and their coordination improved, especially the one representing farmers' interests. Indeed, our study also highlights the mismatch between FBOs' demand and ISSs offer. This risk which is related to the inability of some project settings to support participatory approaches has already been mentioned in other projects (Klerkx et al., 2017; Coq et al., 2012).

To avoid this, in particular, and as the recent innovation policy framing on socio-technological change suggests, FBOs and other grassroots organizations should become part of multi-actor networks within which they could discuss, experiment niche innovations and collectively learn with other types of actors (Faure et al., 2019; Lowe et al., 2019; Schot & Steinmueller, 2018; Knierim et al., 2017). Some organizations need to develop brokerage and facilitation services, especially to support and facilitate informal and flexible networks or temporary associations of actors at the initial phase of innovations and to more formally structure them at a later stage (Klerkx & Leeuwis, 2009). Such settings also imply searching for some innovative types of funding arrangements which could include the development of some ISSs by FBOs for their members. Ideally, the ISS costs should be shared among different types of actors using mixed funding modes in order to ensure their quality and durability (Nettle et al., 2017; Coq et al., 2012).

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LEARNINGS FROM 12 EU/H2020 PROJECTS ABOUT INTERACTIVE INNOVATION: REFLECTIONS ON THE JOINT SESSION IN THE ESEE CONFERENCE, HOSTED BY TEAGASC, IRELAND, IN JUNE 2021

Eelke Wielinga [a], Patrizia Proietti [b]

[a] LINK Consult, The Netherlands
[b] CREA, Italy

Abstract

Interactive innovation is the leading theme in many EU funded projects in Europe. During the ESEE seminar in 2021, hosted by Teagasc, Ireland, a joint session has been organised with contributions from twelve major international projects in the period 2015 - present, in order to find out similarities, differences, common barriers and opportunities for stimulating synergy.

The projects that contributed are: Euraknos / Eureka, IPM, Plaid, AgriDemo, Nefertitti. FairShare, AgriSpin, i2connect, AgriLink, Liaison, Uniseco and NextFood.

The conclusions of this event have not been published so far. IFSA is an opportunity to share the results with the scientific community, and to discuss which issues arise from it for both the scientific and the political agenda.

Key words

Innovation support, interactive innovation, AKIS, European Innovation Partnership programme (EIP), international project management.

Recordings

Pitches: https://www.youtube.com/watch?v=9c26M0684TQ
Summary: https://youtu.be/msFRr0A6mxA

Interactive innovation in 12 EU projects: what did we learn?

After a period in which innovations were supposed to be driven by demand and supply among private partners in the agricultural sector, renewed attention was given in the last decade to the importance of the quality of interaction between farmers, researchers, policy makers and other stakeholders in food and rural development. The European Commission is heavily supporting this movement in its Horizon 2020 / European Innovation Partnership (EIP) programme. This started in 2014 and is prolonged in the new CAP period of 2022-2027. Since then, over 4000 Operational Groups have been -or are being- funded throughout Europe, in which farmers, researchers and other actors work together on developing concrete innovations at farm level. Furthermore, Thematic Networks and other H2020 projects receive EU funding for bringing interactive innovation into practice.

In preparation of the 25th ESEE seminar in June 2021 Tom Kelly (Teagasc), host, and active in a range of H2020 projects, suggested to make use of the opportunity for bringing projects together in an interactive session, in order to exchange experiences and wishes for the future. Twelve EU supported international projects, all focussing on interactive innovation, contributed to the event, which was quite unique for the scientific community: to jointly reflect on work in progress.

Objectives of this event were:

[a] To provide an overview of what is going on in the major EU/H2020 projects on interactive innovation.
[b] To share progress made in the projects regarding the themes of the conference: discoveries as well as questions that still need to be answered.
[c] To create an opportunity for experience sharing co-learning and reflection.
[d] To generate recommendations for policy makers for improving the biosphere in which such projects take place.

Complementarity of the projects

Every project has different objectives and focusses on different aspects of interactive innovation processes. How do they fit into the larger jig-saw puzzle? In an effort to visualise this puzzle, the project representatives were asked to score their orientation on a range of themes along five clusters of key actors in an Agricultural Knowledge and Innovation System (AKIS):

1. *Society*: farmers, actors in the food chain
2. *Experts*: Researchers, technicians
3. *Educators*: Teachers, trainers
4. *Enablers*: managers, policy makers, funding agents
5. *Intermediate actors*: advisors, innovation support agents.

Furthermore, an estimation was made how much emphasis a project gives to:

- *Technical know-how*: technics, economics, data processing and exchange, sustainability.
- *Process know*-how: dynamics of social interaction, methods for participation, co-creation.

During the discussions for preparing the event, a third type of know-how was added:

- *System know-how*: AKIS policies, creating an enabling environment, tools for monitoring.

The result of this quick survey is shown in figure 1.

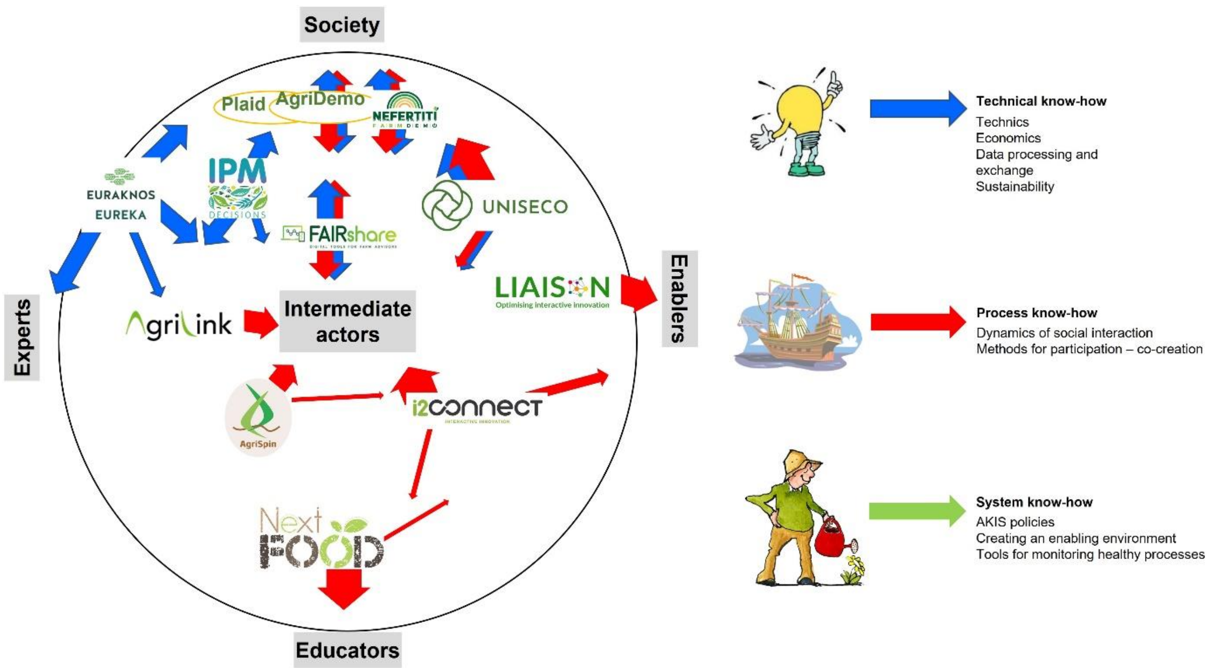


Figure 1: complementarity of 12 projects on interactive innovation

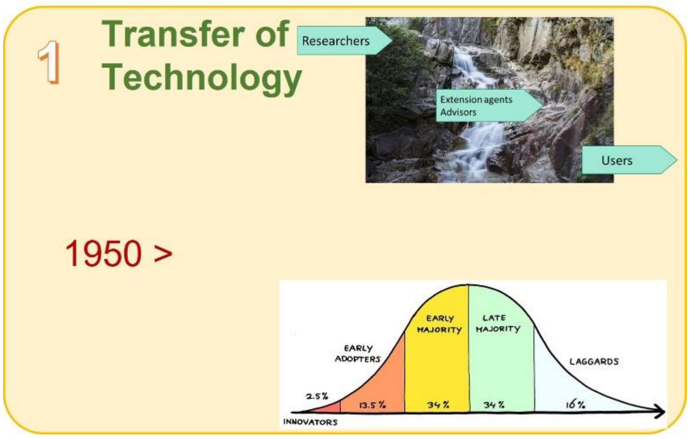
These three types of know-how became the themes for the subgroups in which project representatives discussed the leading questions:

- What are your learnings?
- What do you know by now?
- What is your impact?
- What are your plans and wishes?

The larger picture: 4 successive mainstreams in innovation support

As an introduction to the joint session, the first author of this article placed the current attention for interactive innovation in an historical context.

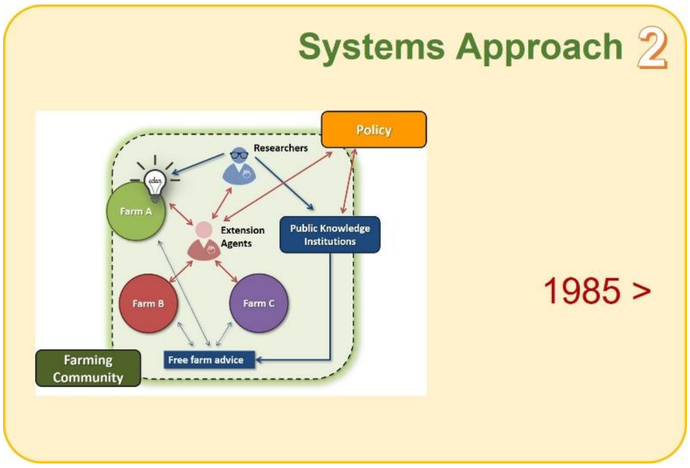
- *Transfer of Technology*



In the years after the Second World War, rapid growth of food production capacity was top priority. Large investments were made in public research institutes, and extension services were seen as public facilities. Knowledge was supposed to flow from research (as the source) via extension (flow) to the farmers (fertile soil). Technicians were in the lead.

In the '60ies, attention was growing for adoption processes. Some farmers are quick to adopt new technologies and others stay behind. In order to stimulate adoption, strategies could be developed by focussing on innovators early adopters first, after which innovations would trickle down to the majority. There will always be laggards who eventually drop out. The adoption curve of Evereth Rogers (1962) became a standard model for extension agents and advisors.

- *Systems Approaches*



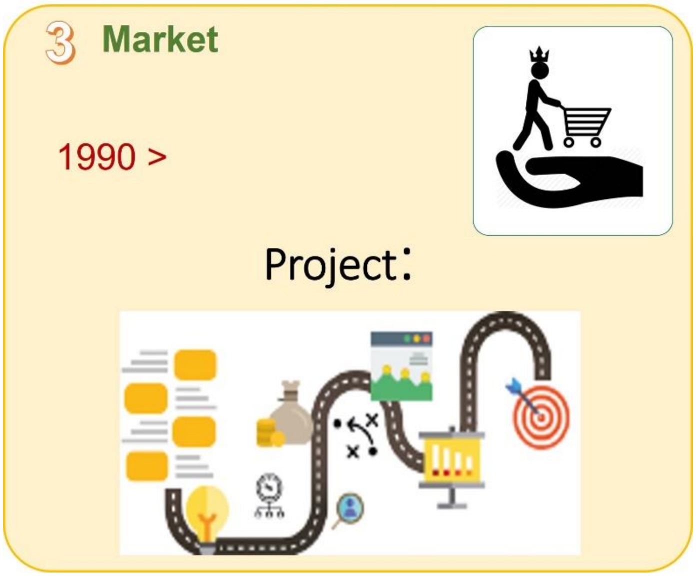
In the '80, awareness grew that the trickle-down assumption could have negative effects for many farmers. So far, the quality of the innovation had been beyond suspicion. 'Laggards' were obviously not so clever and could be ignored. But many farmers had good reasons not to adopt the messages from the technicians. In systems with unequal power distribution, innovations can make some actors rich at the cost of others and limit their access to the knowledge they need.

Furthermore, technicians in their leading role easily ignore relevant knowledge of farmers and their capacity to find new solutions that work for them.

In line with a more general philosophical discourse about society as a system of interrelated actors and connections, the Farming Systems approach became popular among rural sociologists. Instead of just focussing on technical solutions, the entire farming system should be considered by those who aim to stimulate innovations. This includes the economic, social, and political context. Participatory methods were developed in order to give the voiceless a voice in their struggle against oppression (Paolo Freire 1968). It is not the technicians who decide what is best for the farmers: they only assist in the decision-making process of the farmer. 'Extension is assistance in decision making', according to Anne van den Ban (1970).

The capacity of farmers to innovate depends on the quality of the connections between the key actors in a knowledge system. This was the spirit in which AKIS as a concept emerged: Agricultural Knowledge and Information Systems. Information should be distinguished from knowledge: information can be exchanged, whereas everyone develops his own knowledge (Röling 1976, 1988). Innovation support agents have a pivotal role in connecting the key actors in a knowledge system.

- *Knowledge Market*

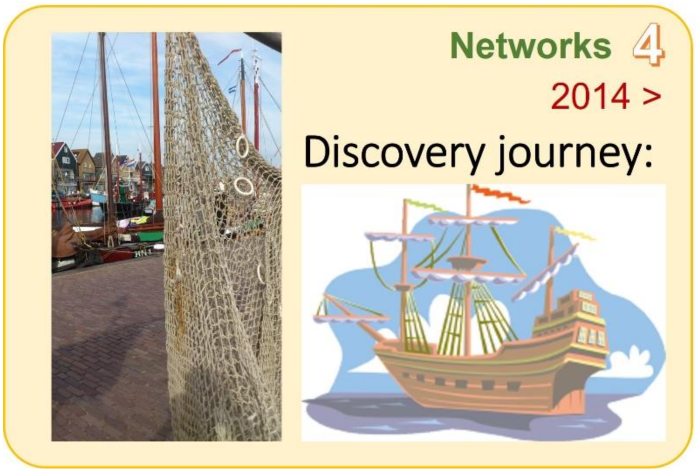


In the ‘90ies, the market became dominant. The commercial sector was supposed to be more effective and efficient than public agencies. Many public extension agencies were privatised. Knowledge became a product. Researchers were producers. Farmers were clients who pay for knowledge. And extension agents became advisors who were supposed to act as salesmen of knowledge products. Public funding agencies had to learn how to become a client in the market for knowledge products that served the commons. Funding programmes followed the rules of product delivery, with clearly defined goals and measurable results.

Interestingly, AKIS as a concept remained in use, although the distinction between knowledge and information was not so relevant anymore in market thinking. Gradually, *information* was replaced by i*nnovation* in the abbreviation.

Several scholars observed that something was missing: the market does not sufficiently take care of the coherence in the knowledge system. When the pivotal role of innovation support agents in connecting key actors is not collectively paid for, the quality of the wiring of the system decreases. Wielinga (2001) pointed out that the role of the ‘Free Actors’ in the once so successful Dutch AKIS had been neglected since the privatisation of the public extension service, with detrimental effects on the innovative capacity of the sector. Klerkx (2008) came to a similar observation and promoted the ‘knowledge broker’ as a concept: agents who match supply and demand in the knowledge market.

- *Networks*



Since the European Commission launched the EIP programme in 2014, the quality of the interactions between the major actors in a knowledge system is back in the focus of attention. It is being acknowledged that not only technicians have valuable knowledge to share, but also farmers and other key actors in the food chain. Solutions are likely to work better for the targeted audiences if they have been actively involved in developing them. Relevant knowledge emerges from interaction.

The EIP programme supports thousands of 'Operational Groups' in which farmers, researchers and other actors are supposed to work together on a concrete innovation at farm level. A range of international thematic network projects and interactive innovation projects are being supported as well, in order to share experiences and feed operational groups with support in different ways.

Network approaches consider the quality of relations between actors involved in which hierarchy is not obvious, and initiatives can be taken by any actor, including farmers. The dynamics in such networks differ from those in organisations or projects with clear targets, mandates, and task divisions (Wielinga and Robijn, 2020). A network that works on an innovation is a discovery journey, rather than a production unit. People come together because they share an ambition. The road is uncertain, and the final result is unknown, otherwise it would not be new.

Obviously, it can be expected that structures that have been developed for market approaches do not immediately fit to what is required for efforts into this direction. Within this context, it is now interesting to see how far the different international projects on this track have come, how they fit together, and what can be done to create a more stimulating environment for interactive innovation.

Presentation of twelve EU projects on interactive innovation

Prior to the event, all participating project representatives were asked how they would like to be remembered. Their statements are shown next to the project logo. During the event they presented themselves in a short pitch. What does or did the project aim for? What are the main achievements? And what are key learnings?

1 EURAKNOS EUREKA — Laying the groundwork for Europe's most widely used agricultural knowledge-sharing medium

https://h2020eureka.eu

Euraknos: 2018-2020

Eureka: 2021-2023: 21 partner organisations in 15 countries.

Pieter Spanoghe (Ghent University, Belgium).

Euraknos and its successor Eureka are forming the network of Thematic Networks. The aim is to collect information that is ready for use, to store it and to make it findable and accessible for users. A major learning of the last two year is that it is a big job to translate scientific knowledge into insights that are concrete, understandable, and useful for farmers.

There is high interest in what the project is doing. The platform will be launched soon[1]. A call to everyone: don't try to do everything on your own. Make use of the platform and let us work together.

[1] https://eufarmbook.eu

2 IPM DECISIONS The IPM platform is the place to go for farmers & advisors for DSS access

https://www.ipmdecisions.net

Harm Brinks (Delphi, Netherlands)

IPM Decisions: 2019 – 2024. 27 partner organisations in 12 EU countries.

IPM Decisions aims to collect and develop decision support systems for farmers regarding pest control. There are many good examples of practices that have proven to be effective, reducing the amount of chemicals and reducing costs. But the application is still limited. The project aims to promote the use of such practices.

The project supports farmers, advisors, researchers, and IT developers. A platform is about to be launched[2] with open access (end 2021). Furthermore, an IPM demonstration network is being built.

3 PLAID PEER-TO-PEER LEARNING: ACCESSING INNOVATION THROUGH DEMONSTRATION Inventor of **on-farm demonstration**, virtual demonstration

https://plaid-h2020.hutton.ac.uk

https://farmdemo.eu

Plaid: 2017-2019. 23 partner organisations.

Claire Hardy (James Hutton Institute, UK)

The project aimed to stimulate on-farm demonstration activities. What is already happening? How can it be reinforced? How can farmers be encouraged to join such demo's? The value of on-farm demonstrations is in the peer-to-peer exchanges. How can such meetings be facilitated?

The project engaged with farmers, industry, research, policy makers, Operational Groups, etc. With a commitment to open science, it produced easily accessible material.

Virtual demonstrations appeared to be possible and useful. Tools for such demo's were developed, which allow participants to immerse in 360^{o} virtual reality experiences, at times that are convenient to them. Together with its sister project AgriDemo F2F the Plaid project paved the way for Nefertiti.

4 AGRIDEMO FARMER TO FARMER On-farm demonstrations

[2] https://www.ipmdecisions.net/platform

https://agridemo-h2020.eu

AgriDemo F2F 2017-2019. 14 partner organisations.

Fleur Marchand (ILVO, Belgium)

The aim of the project was to advance farm-to-farm learning. A European inventory was made of farms engaged in demonstrations resulting in 30 case studies.

The project produced both practical and theoretical output, including a PhD study, on 'spaces for experiential learning'. It showed the importance of accommodative processes of engagement and trust.

Good practices have been converted into design guides, including goals, learning styles and group dynamics. These findings have been embedded in a guide that is available in 11 languages. There is a training kit. This resulted into a request for trainings.

Farm demo platforms have been launched, together with Plaid and Nefertiti. AgriDemo and Plaid became the founding sisters of the Farm Demo Hub *(https://farmdemo.eu).*

5 NEFERTITI FARMDEMO — Creating an EU wide farm demo network. Developing and promoting good practices for farmers to exchange knowledge on a peer-to-peer basis

https://nefertiti-h2020.eu

NEFERTITI: 2019-2023. 32 partner organisations in 17 EU countries

Louis Mira (Consulai, Portugal)

Nefertiti is the follow-up project of the previous two: Plaid and AgriDemo. It is a demonstration network of 32 partner organisations. 45 hubs have been established all over Europe. More than 1000 farm demonstrations have been realised with assistance of the project.

The most important heritage from the 3 projects is what has been learned about methodology for successful peer-to-peer learning between farmers during on-farm demonstrations. With the platform and the hubs, Nefertiti has boasted a movement, that is now taken up by national CAP plans. Demonstration has been adopted as an instrument for stimulating innovation.

6 FAIRshare DIGITAL TOOLS FOR FARM ADVISORS — Support advisors to practically engage with and implement digital tools using a **living lab** approach

https://www.h2020fairshare.eu

FAIRshare: 2018-2023. 31 partner organisations. 4 regional hubs for almost 30 countries in Europe.

Tom Kelly (Teagasc, Ireland)

The project addresses the digitalisation of advisory services. FAIRShare is the acronym for Findable, Available, Interoperable, Reusable and Sharable. It is a € 7M project and it is over halfway through its 5 year period.

There are two objectives:

[1] Sharing existing digital tools and services being used in advisory services.

[2] Funding practical use and engagement with digital tools and services at advisory level across Europe using a 'living lab' approach via the development of User Cases.

Where are we now? We have developed a Permanent Network Facility (PNF) with over 260 digital tools and services, ranging from communications and analytical tools to advisory organisation tools, etc. To date, we have collected over 50 good practices and our first iteration of good practice vignettes have been developed. We have also developed our training frameworks: an assessment tool and we have made a field analysis of challenges for both farmers and advisors. We have 29 large User Cases underway with a further 13 smaller user cases undergoing selection at the moment. These user cases aim to facilitate farm advisors to practically engage with digital tools in a number of ways.

A key learning so far is that degree to which farmers use digital tools is heavily influenced by their advisors. But not all advisors use digital tools to the same extent. There is a big digital divide.

Another learning was about a motivating environment. At the start we tended to look at tools and trainings. But then we found out to our surprise that the motivational side of an enabling environment appeared to be most challenging. And then the COVID situation turned out to be very helpful to highlight the importance of digital tools and services!

7 AgriSpin

What do advisors actually do to support interactive innovation?
Cross visit methodology.

http://agrispin.eu › wp-content › uploads › 2017/08

https://cordis.europa.eu/project/id/652642

AgriSpin: 2015-2017: 15 partner organisations in 13 EU countries

Andrea Knierim (University of Hohenheim, Germany)

AgriSpin was the first Thematic Network in the EIP programme, collecting experiences on specific topics across borders. The aim was to create space for innovations, by amplifying good examples from Innovation Support Services. The project studied innovation cases through cross visits.

Selected examples, presented by host partners, were visited by team composed of colleagues for other partners. The cross visits had a duration of 3-4 days, and visiting teams consisted of 7-10 colleagues.

The methodology developed in AgriSpin has been modified and widely spread in Europe. Several tools to better understand innovation processes emerged, such as the Spiral of Innovations, the timeline and rich picture analysis, 'pearls and puzzles', and a way to categorise innovation support services.

A key finding was that innovation support agents often made the difference in interactive innovation processes by connection the right partners in the right moment.

8 i2connect — Training and coaching for innovation support agents. Toolbox for advisors, trainers and enablers

https://i2connect-h2020.eu

i2connect: 2019-2024. 42 partner organisations in 23 countries

Sylvain Sturel (APCA France)

The project focusses on the role of farm and forestry advisors in interactive innovation processes, in support of the transition towards a more sustainable agriculture in Europe.

It is is a young project, with three main objectives:

- To strengthen the skills of advisors
- To strengthen the role of advisors in the wider AKIS
- To create a European network of innovation advisors

The project has a scientific component: to collect literature and to organise reflections. In almost all EU countries it searches for practical cases to be better understood and described. A toolbox is being developed for training modules for different target groups: advisors, trainers, enablers, and educators. Training courses and cross visits take place, and the project aims to create a professional network for continuous sharing and learning about interactive innovation processes. For doing so, it relies strongly on existing networks: IALB, EUFRAS, FiBL, SEASN. All these umbrella organisations are actively participating in i2connect.

Achievements so far: the inventory of AKIS descriptions, that has been made in the ProAkis project (2011-2014) has been updated. A study on necessary competences of innovation advisors is ongoing. A database of advisors throughout Europe is being built. And trainings for trainers and advisors are being carried out. It is a network project with many practical activities, rather than research.

9 AgriLink — Better understand role of advisory suppliers. Enhance their contribution to learning and innovation.

https://www.agrilink2020.eu

AgriLink: 2017-2021. 16 partner organisations in 13 countries.

Pierre Labarthe (INRA France)

AgriLink stands for Agricultural Knowledge – Linking farmers, advisors, and researchers to boost innovation. Our ambition was to stimulate transition towards sustainable agriculture, by furthering the understanding of the roles of advisory suppliers in farmers decision making and enhancing their contribution.

From the academic perspective, AgriLink wanted to develop new concepts, with strong empirical basis. Interviews were made with 1100+ farmers and 300+ advisors. The concept of 'microAKIS' and farm advisory regimes emerged.

For policy making, recommendations were made, well informed by data about the relation between demand and supply for advisory services in various areas. The link between the project and policymakers was short, thanks to informal connections in the ScarAKIS group for example.

For advisors, new methods for co-designing innovative methods and pedagogical material have been developed. The LivingLab approach for joint learning between farmers, advisors, and researchers was promoted successfully.

We learned that there is a huge heterogeneity of microAKISes between farmers. Many farmers only rely on one or two main suppliers of information. Digitalisation changes the landscape of informal connections.

10 LIAISON Optimising interactive innovation

Optimise the interactive innovation project approach as promoted by EU. Speed up innovation in rural areas

https://liaison2020.eu

Liaison: 2018-2021. 17 partner organisations in 15 countries.

Susanne von Münchhausen (Eberswalde University for Sustainable Development, Germany)

The aim of the project was to optimise innovation processes by linking actors, instruments, and policies through networks. It is a research and innovation project. Now we are in the dissemination phase.

For developing the methodology, we made a conceptual framework, and then we made consultation rounds with multi-actor stakeholder groups in four European Regions: Nordic/Baltic, Danube/Balkan, Mediterranean, Atlantic/North Sea. After this we started funnelling. There was a contest with 175 entries, 200 cases were reviewed (light touch), and 15 cases were studied in-depth.

Then we nominated 15 rural ambassadors who were rewarded with a video. These videos are now available. There is a fancy over-all video, which you can use for your own events when you want to explain about interactive innovation. In the catalogue you can find 35 cases. There is an interactive map. Several scientific papers have been published. And in September 2021 the final conference will be held.

11 UNISECO

Enabling co-learning between different actors involved in agro-ecological transitions. **Multi actor platforms** *https://uniseco-project.eu*

UNISECO: 2018-2021. 18 partner organisations in 12 countries.

Gerald Schwartz (Thünen Institute, Germany)

The name of the project stands for '**UN**derstanding and **I**mproving the **S**ustainability of agro-**ECO**logical farming systems. The main aims were to improve the understanding of agro-ecological processes and impact on the transition in different contexts across in Europe, and to initiate and co-develop with local actors new solutions, as well as strategic pathways in order to enhance transitions.

We looked into questions such as: (a) What are the sustainability impacts of implementing different combinations of agro-ecological practices? (b) What are barriers? (c) Why could not they be overcome in the past? (d) How can they be addressed in the future?

Multi actor platforms were a central element in the project, to stimulate continuous engagement of different actors: farmers, advisors, different rural community representatives. Who could be potentially engaged in agro-ecological transitions?

The focus was on co-learning, in particular about the roles of different actors. Who are they? Who should be invited as well to join? When these roles are properly understood, the next step was to propose jointly strategic pathways to how to move forward.

We did this in case studies that covered rather conventional systems. There it was about initiating agro-ecological transitions. Other cases were more on enhancing ongoing transitions.

What stands out is the importance of knowledge sharing and knowledge creation. We have seen the important role of trusted advisors as intermediaries and champions in building the trust between the different kinds of actors that are needed to do so.

There was also a focus on young generation. Linking the knowledge creation and the awareness raising with vocational schools, public school programmes, and here also the particular role of farmers and advisors in terms of exchanges about innovations.

On the Uniseco website story maps can be found that tell the experiences from the perspectives of the various actors involved. This is interesting read.

12 NextFOOD Educating the next generation of farmers and advisors

https://www.nextfood-project.eu

NextFood: 2018-2022. 19 partner organisations in 13 countries (including 3 outside Europe)

Martin Mellin (Swedish University of Agricultural Sciences) 51:30

Next Food is short for 'Educating the Next Generation of Professionals in the Agricultural Food System'. It is a research and action project, which started 3 years ago, and we still have one year to go. We developed new ways for educating future sustainability leaders of the agri-food and forestry sector. The purpose is to make sure that the professionals (farmers, advisors, business representatives and students) have the right set of skills and competences for the sustainability challenges ahead: food security in the context of climate change, loss of biodiversity, etc.

Most of the 19 partners are from the EU, but some come from outside outside: Egypt, Ethiopia, India and Chili. Most of them are universities, but there are also NGO's, business networks and intermediaries.

We developed a roadmap for transforming education. It will be tested and evaluated in a learning process of four steps. [1] Gather empirical data from food system actors: what skills are necessary in the future? These are compared with existing curricula. Where are the gaps? [2] Action oriented educational approach. The starting point is the lived experience of the students: they lived in farms or in communities. [3] The new approach is tested in different contexts: geographical areas, parts of the food system, cultures. [4] Evaluate the barriers and opportunities for the learners (students, teachers and institutions) to adopt the NextFood learning approach.

The basic idea in NextFood is to challenge the conventional learning model, where knowledge is seen as a package that can easily be passed on to passive receivers. Instead, we focus on transdisciplinary and action-oriented learning model where learners learn in action and in interaction with others (farmers, field experts).

Summaries of the sub-sessions

After the representatives gave their pitches of the projects, they were divided into subgroups, following the three knowledge orientations mentioned earlier: Technical know-how, process-know-how and system know-how. There they discussed the following questions:

a) What do we know by now?
b) What did we learn?
c) What is our impact?
d) What are our plans and wishes?

At the end of the lively sub-sessions, the chairmen summarised the most important conclusions that emerged from the discussions.

Sub session 1: innovative knowledge.

Chair: Magnus Ljung
Projects represented:

Innovative knowledge	*cluster 1*
Euraknos	Pieter Spanoghe
IPM Decisions	Harm Brinks
Plaid	Claire Hardy
AgriDemo	Fleur Marchand
Nefertiti	Luis Mira

Fairshare	Tom Kelly
chair	Magnus Ljung

Need for long term perspectives

Projects always have a limited period for delivering results. Developing knowledge in an interactive way is an ongoing process. It takes time to build contacts between professionals in different regions and sectors, and to establish trust. By the time a project gets leverage, it stops.

Some projects manage to build professional platforms for exchange and development. But also, these platforms stop when the projects funds dry up.

Need for more flexibility in using funds

Projects feel little room to deviate from the planning for which it receives funding. When experts meet colleagues in other projects and see possibilities for collaboration, this was not foreseen in the planning and joint activities seem to be impossible within the current projects.

Tension between project frames and desired movement

The movement all projects try to enhance is developing innovations through collaboration, by trial and error, by discovery and coping with unexpected events and outcomes. The way in which international projects are currently framed, with clearly defined deliverables and detailed planning for producing them is not appropriate for this desired movement.

No room for failure

Is it OK to fail? The answer is no. This affects the risks people are prepared to take, while innovation efforts are inherently risky.

Sub session 2: interactive innovation processes.
Chair: Alex Koutsouris
Projects represented:

Innovation processes	*cluster 2*
AgriSpin	Andrea
i2connect	Sylvain
AgriLink	Pierre Labarthe
Liaison	Suzanne von Münchhausen
Fairshare	Teresa Hooks
Uniseco	Francesco Vanni
chair	Alex Koutsouris

No standard for innovation processes
There is a great diversity in innovation processes that can be observed. Under different conditions and regional contexts such processes develop in different ways. It is impossible to say what is best.
Several projects have produced models for identifying phases, with which interactive innovation processes can be described:

- AgriSpin: the Spiral of Innovations. 7 phases.
- AgriLink: The Triggering Model. 3 phases.

Sometimes phases can overlap.

Where do innovation support agencies enter?

It can be concluded that agents are needed in every phase, where they do different things. Consequently, there is a great diversity of innovation support agents and the roles they perform.

The issue of trust
Farmers usually make use of one or two trusted agents. Trusted intermediates are very important. It is said that they should be independent. But practice is divers. For example, in high tech companies are important drivers of innovation, and their highly qualified agents usually are trusted.
When it comes to issues regarding the commons, such as environment and animal welfare, public and farm-based organisations as well as NGO's are more important.
Sometimes it can be questioned if agents from such organisations represent the real world.

Networks are very important

For interactive innovation processes, building networks is crucial. This requires new capacities and skills of support agents.

Part of this is the insight and capacity to provide the right service on the right place and the right moment.

Digital skills have become high priority for innovation support agents

Mindset to reflect

To a large extend the necessary insights and skills for guiding interactive innovation processes must be acquired through learning by doing. This requires a mindset of reflexion and capitalising the learnings.

It is great when professionals take time to reflect, preferably with peers.

But many agents do not experience the space for doing so within the current management culture, which is target oriented and money driven. Under pressure, time for reflection is often the first victim.

Sub session 3: enabling environment.
Chair: Laurens Klerkx
Projects represented:

Enabling environment	*cluster 3*

Nextfood	Martin Mellin
Uniseco	Gerald Schwartz
AgriLink	Jorieke Potters
Liaison	Anna Häring
i2connect	Jos Verstegen
chair	Laurens Klerkx

Similar difficulties in various circumstances
Although the external environment is very different throughout Europe, many of the difficulties that projects encounter are similar. What differs is how people in different countries deal with them.

Innovation processes are unpredictable
Within the H2020 environment there is tension between the needed flexibility and project structures of projects. This has to do with the preparation phase in which you have to say: "We work with 'Living Labs". But then, during the project period you discover that this approach is not the most appropriate one for the circumstances. The type of approach needs to be adjusted to the situation at hand. Projects should have a good diagnostic phase after which you can choose the proper approach, but this is not accommodated.

Innovation as a journey.
The structure with milestones, fixed work packages, etc. does not follow the dynamics of a journey. Projects encounter unexpected barriers, for example at the institutional level, that take more time to deal with than the project agreement allows for. Rather than to check if everything has been done what was promised.
Mid term evaluations could become more useful if these were moments to reflect, to learn from what has been encountered, and to adjust the project accordingly. But such reflexive monitoring is quite a task, and that requires capacity. Which often is missing. Not only within the project, but also in the external environment. You need project officers who can think along, while we usually find the tick boxing practice to be dominant. Making amendments on the project agreement should not be the last resort, but a kind of standard for changing the course of a project.

People have different expectations
Advisors have to reach their targets. What do people get back in uncertain projects on innovation? It should become clearer what would be the payback in the long end for the time they spend in the project. What is the revenue model? These are not so much the needs of the funding agency but those of the people you work with in a project. Take time to clarify expectations about the gains.

People have different mindsets
People in a project might have different mindsets, that might be related to their generation. It requires attention to transfer experience over generations, otherwise you

keep on doing projects with the same people who feel comfortable with each other. That needs to be accommodated in the project design, and this is often not the case because there is too much pressure on producing results.

Some remarks concluding the session

There is a lot to learn from the exchange of the different projects. Actually, we should take time to sit down together with key persons from different projects to see what we can learn from each other. But where do we find the time when this is not foreseen in the project design? We really need to develop new approaches to build in this flexibility into project schemes.

It also a kind of thinking at the level of the enabling environment that allows for discovery, rather than checking deliverables. We need tools that feed trust and enable.

In the preparation of this joint session, Inge van Oost (European Commission) explained enthusiastically about new possibilities for supporting Operational Groups: measures that already are into the direction of providing space for discovery[3]. But meanwhile at the level of for example the Dutch Provinces that are responsible for managing the OG schemes, or the national subsidy agency checking all the subsidy expenses, there is a lot of fear for what 'Brussels' supposedly does not allow. Maybe we have to organise also the interaction between the Managing Authorities in the member states and the auditors of the European Commission.

Reflections and new opportunities in the CAP 2022-2027

Puzzles

Projects versus discovery journeys

The joint session on international projects for interactive innovation under the H2020 programme of the EU made clear that these projects encounter a number of structural difficulties, due to the tension between the political and financial structure in which they are framed and the dynamics that are inherent to the ambition to create new things together. The structure is fit for production processes with clearly specified outcomes and pathways to produce measurable deliverables. The dynamics of multi-actor projects are more like discovery journeys, with a shared ambition as a reason to embark, and lots of unexpected events underway which require flexibility and the capacity to respond in unforeseen situations.

In the multi-actor approach, the development and implementation of an outcome/innovation involves a diversity of actors in iterative and joint learning processes. To be productive, such processes require creating conditions in which solutions and ideas can be discussed by effectively combining each other's knowledge, perspectives and resources. This is hardly the case in projects with a limited lifetime and a strong result-orientation (both Horizon projects and operational groups): already at the planning stage, all resources are allocated to achieve expected results within the set timeframe. The

[3] She was supposed to give her input at the end of this joint session, but unfortunately, she she had to cancel it in the very last moment. In the last chapter, a summary of her input is given, and updated with the latest developments (early 2022).

pressure to achieve results and the focus on delivering measurable outputs leaves no room for discussion, reflection and capitalisation of results.

What tools to monitor progress?

Deliverables and milestones are needed to monitor the project's progress and gain insight into the efficiency of spending, but are they the only effective tool? Would it be possible to envisage the introduction of mechanisms for rewarding/incentivising and monitoring knowledge co-production processes?

Progressively involving partners does not fit into current project agreements

The multi-actor approach has led to an enlargement of partnerships which aim to foster the integration of different knowledge not only in terms of types of actors but also of geographical coverage. However, the involvement of many players, who enter the project with different motivations, interests, and resources, often results in growing complexity in managing exchanges and reflections as well as in creating a climate of trust, which undermines the effectiveness of multi-actor approaches. This is not always due to a failure in combining knowledge and visions, but also to a difficulty in actively engaging actors who have different timescales, perspectives, and attitudes towards research. Indeed, the development of a common vision and the sharing of knowledge building processes require time, involvement, listening to the different needs and points of view of other partners.

Therefore, the question of how to actively involve all actors from the planning phase onwards in productive interactions still remains open: how can high quality knowledge exchange activities be improved throughout the project? What actions can be really effective to involve practitioners and make them invest more time in the co-production process? It is not only a question of identifying the most appropriate facilitation methods....

How to involve multipliers and intermediaries?

How to improve the impact of the multi-actor approach is still an open question. In spite of the efforts made by the programme maker to improve the dissemination and exploitation of results, there are still many shadows on the extent to which Horizon projects impact on the ground. The ability to build networks is crucial. For this reason, the involvement of multipliers (e.g., representative bodies or networks) who are already part of broad networks has become a prerequisite for partnerships. The high level of "presence", however, risks being a double lever for these actors, requiring ever greater efforts and resources to effectively channel communication between different levels of the knowledge system even in the face of multiplying inputs. Achieving effects aimed at accelerating dynamism towards more sustainable agri-food systems requires specialised and focused competencies in influencing change by linking actors and activities, skills, and resources, and creating collaborations between different levels of knowledge generation. While intermediary actors having such competences are indeed available in all EU Member States, their participation as project members would considerably enlarge the dimension of partnerships, thus increasing their manageability. Actually, new capacities and organisational models are needed. New governance models are also required to legitimise and facilitate a possible intermediation role. Which governance model could fit the need to keep an efficient partnership management while allowing intermediary actors to get ownership of the project results? What approaches could be used to establish iterative learning loops between research (European level - Horizon) and innovation (local level - operational groups)?

Activating synergies between international projects

Another interesting aspect to maximise the impacts of multi-actor projects concerns the possibility of activating synergies between projects funded at European level (e.g., HE, Erasmus+, etc.). The high level of competitiveness in the calls leads to maintain an absolute level of confidentiality on project proposals. Therefore, possible synergies and common objectives only become known after the projects have started, usually with the beginning of the communication phase. Although dialogue can be built at any time, each project remains committed to the submission of its own deliverables, which may also be very similar to or overlap with other projects. This, in addition to creating possible confusion among end-users, may compromise the development of complementary outcomes and synergies in both knowledge generation and impact maximisation. The question we are asking is whether there is a way to facilitate connections between projects and to create common working paths, thus contributing to a better use of resources.

Opportunities in the new programming period

Instruments for reinforcing AKIS in Member States

The new Horizon Europe and CAP planning under the common EIP-AGRI framework envisages a strengthening of Member States' AKIS to advance knowledge exchange and build capacity in support of the Green Deal, CAP and farm to fork objectives. The aim is to organise future AKIS as inclusive strong knowledge ecosystems at all levels, by integrating, without constraints, all those who generate, share and use knowledge and innovation for the development of agricultural systems, enhancing knowledge flows between the AKIS players (farmers/foresters, advisors, researchers, organisations, NGOs, networks, education, retailers, media, services, various ministries) as well as strengthening links between research and practice.

Achieving this goal requires insights and tools to interconnect actors within the AKIS and link them with practice-oriented information derived from different sources that are readily available.

To this aim, the CAP Strategic Plans regulation, under the cross-cutting objective, requires Member States to:

(i) have impartial advisors integrated within the AKIS covering all sustainability fields with up-to-date knowledge and information, needed to achieve the Green Deal objectives and targets

(ii) provide support for knowledge exchange and information events, including for advice, demo and training, thematic and cross-sectorial events,

(iii) provide innovation support for operational groups, from grassroots ideas to project development and drafting,

(iv) organise CAP networks to connect AKIS actors, as well as existing operational groups and interact with Horizon Europe National Contact Points (NCPs).

Knowledge repositories

Regulatory provisions highlight a growing need for actors and tools able to support, mediate, multiply knowledge and integrate different sources of information. In this perspective, the new CAP broadens the role of Networks, which will no longer be called Rural Networks but CAP Networks, and will have, among others, the role of supporting the development of connections between research/practice, trans-national/national/local knowledge systems (Horizon Europe/other national instruments). The supporting role of knowledge repositories collecting information on all MA projects in the Member States is also emphasised, both at the wide EU level, with the funding of the EU FarmBook platform, and the national one. The aim is to make an increasing volume of practice-oriented knowledge easily accessible at EU level and foster knowledge-sharing platforms.

Creating access to novelties

These novelties will also be supported through the Horizon Europe programme, which provides a specific budget of EUR 10 billion for issues encompassed by the European Green Deal, the Farm to Fork Strategy and the CAP, the Biodiversity Strategy, and the wider bioeconomy policies. Specific calls have been issued to:

- improve preparation of multi-actor projects to enable the relevant actors to work in a co-creative way (HORIZON-CL6-2022-GOVERNANCE-01-14),
- support knowledge exchange between all AKIS actors in the Member States (HORIZON-CL6-2021-GOVERNANCE-01-24),
- improve national AKIS organisation across the EU (HORIZON-CL6-2021-GOVERNANCE-01-25),
- deepen the functioning of innovation support (HORIZON-CL6-2021-GOVERNANCE-01-26),
- broaden EIP Operational Group outcomes across borders (HORIZON-CL6-2021-GOVERNANCE-01-23),
- mobilise the network of national contact points in Cluster 6 (HORIZON-CL6-2021-GOVERNANCE-01-01),
- develop EU advisory networks on consumer-producer chains (HORIZON-CL6-2021-GOVERNANCE-01-27),
- and further topics.

Funding for Multi Actor Approaches

Furthermore, in cluster 6, the multi-actor approach is strengthened and streamlined as an eligibility criterion for funding. In their CAP Strategic Plans, Member States will need to scale up support for EIP-AGRI and AKIS. This entails a stronger targeting of end-users' needs and opportunities, the involvement in consortia of key relevant actors with complementary knowledge, including local interactive innovation groups, able to ensure a broad implementation, the active participation of all actors from the planning phase onwards. The process of cross-fertilisation, i.e., exchange of high-quality scientific, tacit-and practical knowledge throughout the project, should be facilitated by the most appropriate methods and proven through demonstrating its added value.

How far could new regulatory provision and instruments solve the problem?

The instruments provided through the Horizon Europe programme and the new CAP framework to strengthen AKISs and knowledge flows within them seem to address some of the gaps previously identified.

Independent advice and intermediaries

The two most relevant opportunities within the new CAP certainly concern the reinforcement of the role of advice within AKISs and the strengthening of networks as intermediaries for innovation. The framework set out by the European Commission gives the Member States broad room for manoeuvre, but the question is whether the different administrative systems will be sufficiently prepared to use the tools effectively.

Much depends on national implementation

Certainly, the institutional arrangements of the different Member States will play a key role in the implementation of these measures, for instance in terms of differences between those Member States that have public advisory services and those that have pluralistic ones. The integration of advisors into the AKIS requires the development of a system perspective. The question is what strategies, mechanisms and policy instruments should be put in place to promote and support the effective empowerment and integration of advisors within the AKIS. The answer to this question concerns not only decision-makers, but all relevant actors in the AKIS: what strategies, policy mechanisms and tools should be put in place for farmers, advisors, policymakers, researchers/academics to engage in stronger interconnections with advisors?

Again, to what extent do advisors in different socio-economic contexts and with different backgrounds perceive the need/opportunity to better integrate the AKISs? What barriers/obstacles do advisors experience when interacting within the AKIS, and how are Member States addressing this issue (if at all), and what are their strategies?

Moreover, it will be interesting to understand how innovation support services and back-office services for advisors will be organised, as they could represent, if appropriately organised, important moments of connection between different type of knowledge, actors and domains (e.g. innovation/back office hubs).

The important role of CAP networks

Of great interest is the role of the CAP Networks, which are called to foster the strengthening of knowledge exchanges on all 9 CAP objectives, contributing to the development of an innovation-friendly environment. They are expected to systematise (and translate) all the resources (in terms of knowledge) resulting from operational group projects, Horizon 2020 multi-actor projects, the EIP-Agri website and new knowledge reservoirs. Linking all this information undoubtedly provides an impressive knowledge pool for local AKIS actors, which could be used for training, peer-to-peer events, on-farm demonstrations, websites, and other dissemination activities.

To support the exchange of knowledge and the strengthening of innovation, the PAC networks should organise knowledge events and platforms where all AKIS actors could meet regularly to discuss problems and opportunities, building connections with existing projects, even beyond national borders.

In the new programming period, therefore, the CAP Networks are called to be more proactive, promoting OGs and their work, exploring Horizon themes, and inviting actors from both sides to collaborate around specific themes. This means intensifying synergies between OGs and Horizon groups, between CAP networks and the National Contact Point (NCP - Horizon Europe). This role of multi-level intermediary is certainly aimed at overcoming many of the critical points highlighted above. However, it is a very ambitious task that requires significant human resources in terms of time and skills.

High demands on expertise of the implementors

To carry out these functions, networks should be equipped with employees having adequate technical, communication and soft skills, as well as reorganise their activities. Moreover, policymakers and managing authorities should be able to plan these activities, which also require interconnections between different policies and sectors, such as research and innovation supported under the rural development umbrella, which, as the recent i2connect study shows, are generally organised by different managing authorities. Once again, Member States will play a key role in designing multi-level and cross-sectoral governance that fosters coordination and complementarity between multi-actor projects and, above all, between different levels of political and administrative responsibility.

The Horizon Europe programme certainly includes some interesting new features. For instance, the compulsory participation of operational groups in thematic networks should facilitate the exchange between research and innovation projects at territorial level.

Moreover, some recent calls are open to the implementation of projects running over a period of several years (up to 5-7). However, the extension of the period corresponds to a multiplication of deliverables and milestones and does not help solving the problem of building common vision and trust among the consortium partners.

Calls for proposals on connecting actors and bridge builders

Certainly, some of the projects announced in cluster 6, which have the objective of connecting actors and bridging knowledge, could facilitate the development of new models of governance at Member State level, thus supporting the process of strengthening AKIS envisaged in the CAP regulation. However, these projects should be able to coordinate in order to identify possible synergies and maximise territorial impacts. With the ModernAKIS (HORIZON-CL6-2021-GOVERNANCE-01-25), ATTRACTISS (HORIZON-CL6-2021-GOVERNANCE-01-26) and EU-FarmBook (HORIZON-CL6-2021-GOVERNANCE-01-24) projects, this synergy has already been explored in drafting the proposals, but opportunities for dialogue and interaction, that go beyond formal exchange, should be identified among all the projects of the cluster.

Knowledge repositories need to be embedded into supporting structures

One last consideration, among many others, concerns the development of knowledge repositories. The repository is undoubtedly a relevant knowledge infrastructure, but it should be supported by appropriate tools able to deliver knowledge to the final users. It is not sufficient that documents can be immediately accessible in terms of location and comprehension (and here we might also ask ourselves how the outputs of all research and innovation projects could be translated into immediately usable knowledge), but it is also necessary that this knowledge can reach all end-users, not only the pioneers or innovators, who are familiar with digital tools, but also the 'silent non-participating' actors.

INNOVATING AMIDST A WEAK AND FRAGMENTED AKIS: EXPLORING THREE GREEK CASES

Alex Koutsouris, Helen Zarokosta

Agricultural University of Athens

Abstract

Based on the idea of farmers' micro-AKIS (Agricultural Knowledge and Innovation Systems), developed within the AgriLink (HORIZON2020) project three innovative Greek cases are explored aiming at identifying the actors (and their roles) who supported farmers along the innovation process (from awareness, to assessment to implementation) following the 'Triggering Change' model claiming that major changes in farming occur as a result of trigger events that deviate farmers from the dependency path they are locked-in and bring them in a fragile position while searching for support in assessing and implementing innovations. The innovative cases explored concern: a) the cultivation of stevia in the area of Karditsa (Central Greece); b) the cultivation of avocado in Chania (Crete); and c) the implementation of a method of sexual confusion of insects in the framework of Integrated Pest Management in Imathia (Northern Greece). These innovations took off amidst the weak and fragmented Greek AKIS, notably the demise of the public Greek extension service. And while there has been a number of studies exploring this at the macro-level, the utilization of the concept of micro-AKIS, on the one hand, sheds light on the question who supports farmers (at the local level) to take up innovations and, on the other hand, supplements the macro-level studies.

Introduction & Conceptual framework

The Greek Extension Service has, during the last three decades, been in a painful process of bureaucratisation leading to its absence from the rural development field. This largely owes to the fact that following the accession of Greece into the EC (1981), the administrative burden of the Common Agricultural Policy (CAP) implementation was designated to the Extension Service. However, no major functional re-structuring of the Service took place; thus, extensionists were entrapped in a bureaucratic-administrative role. Extensionists became more than ever severely restricted vis-à-vis the provision of advice to Greek farmers; information was provided to those of the farmers who actively sought for it albeit in a rather fragmented, inadequate and inefficient manner. Furthermore, changes, which took place in the mid 90s, such as the Ministry divisions' restructuring, the decentralisation of services and the establishment of semi-autonomous organisations for training and research respectively did not yield any substantial positive effects and did not make extension services more flexible and relevant to the needs of farmers.

In addition, the remarkable cultural homogenization of the extension field in Greece, implying the existence of a dominant culture restricted within a narrow 'progressive farmer strategy' and Transfer of Technology (TOT) model (see Koutsouris, 2018) has to be underlined (Lioutas and Charatsari, 2011; Papaspyrou and Koutsouris, 2018).

Such a situation has been verified by a number of studies which have attempted to explore both farmers' perceptions about the Service's interventions and the intervention policy and practice of the Service. (see, inter alia, Koutsouris and Papadopoulos, 1998; Koutsouris, 1999; Gidarakou et al., 2006; Alexopoulos et al., 2009; Charatsari et al., 2011; Kaberis and Koutsouris, 2012; Pappa and Koutsouris, 2014; Österle et al. 2016; Lioutas et al., 2019; Charatsari and Lioutas, 2019). Thus, for example, Koutsouris and Papadopoulos (1998) have criticized the mainly bureaucratic role of public extensionists given that they have abolished their advisory role due to their involvement in controlling the implementation of Regulations and farmers' applications for subsidies and compensations, often creating a tension between extensionists and farmers. In this respect, Kaberis and Koutsouris (2012), Pappa and Koutsouris (2014) and Charatsari and Lioutas (2019) point to the negative perceptions of Greek farmers vis-à-vis public agronomists who are nowadays conceived of as 'bureaucrats' not serving farmers' interests. Such an inefficient and inadequate advisory function is found to be a key factor with respect to the current socioeconomic and environmental problems facing the Greek agriculture (see Alexopoulos *et al.* 2009) while also eliminating farmers' willingness to engage in public extension activities (Charatsari et al., 2011).

The vacuum created due to the weakness of the public as well as of farm based organizations to provide efficient advisory services to farmers is covered, locally, by private agronomists - consultants and input suppliers (Koutsouris, 2014; Kaberis and Koutsouris, 2012). Private consultants mainly support farmers interested in having access to EU programmes so their scope is rather limited. Input suppliers/retailers (private agronomists) provide advice for free in the framework of their commercial activity. Their shops are the main points where farmers seek and obtain free information on inputs and technical requirements; shops, in turn, generate income from the trade of inputs. On the other hand, Michelsen *et al*. (2001), Dinar *et al.* (2007), Kaberis and Koutsouris (2012) and Pappa and Koutsouris (2014) clearly point to the potential conflict of interest arising from the involvement of private agronomists (input providers) in the provision of advice.

Private agronomists/companies also support producers' groups mainly in the framework of Integrated Production schemes, thus constituting an exemption to the general "rule", according to which technical advice is not paid, since in their case the provision of advice is their exclusive job.

At the same time, on the international scene, based on Systems of Innovation (SoI) approaches, there has been a conceptual shift in agricultural extension literature from the ToT model to network and systems approaches (see Koutsouris, 2018). In the latter, the major role of extensionists/advisors is that of the co-learning facilitator ('facilitator' or 'broker'), bringing together stakeholders, organising the dialogue among them and stimulating change and innovation. However, according to Papaspyrou and Koutsouris (2018), Greek extensionists/agronomists are not equipped and do not seem proficient to get involved in the emerging paradigm of advisory services. In parallel, Greek extensionists do not seem to be in a position to comfortably follow the current developments within the EU policy - and practice (Österle et al., 2016), according to which networking, knowledge co-creation and collaboration between different partners in AKIS are becoming of paramount importance as means to stimulate innovation (Koutsouris, 2018).

Given the abovementioned considerations, especially the highly fragmented farm advisory landscape, characterized by complexity as well as by extremely weak linkages and lack of coordination among the AKIS actors (Koutsouris 2014), one would wonder how innovations are generated and/or disseminated in Greece. To answer this question three innovation cases from Greece were explored in the framework of the AgriLink project:

1. The case of mating disruption (MD; also known as 'sexual confusion');

2. The case of avocado in Chania (Crete);

3. The case of the cultivation of stevia in the area of Karditsa (Central Greece).

The analysis is based on two concepts as conceived within the AgriLink project proposal. The first one 'reduces' the concept of Agricultural Knowledge and Information Systems (AKIS; see Koutsouris, 2018) to the local level defining the micro-level AKIS (micro-AKIS) as the knowledge system that farmers personally assemble, including the range of individuals and organisations from whom farmers seek services and exchange knowledge, the processes involved, and how they translate this into innovative activities (or not). The second one concerns the Regional Farm Advisory System (R-FAS) denoting the full range of organizations providing advice to farms in a given region, and their connection to wider AKIS organizations. Furthermore, the description of the innovation cases is supported by the 'Triggering Change' model of farm decision-making (Sutherland et al., 2012). Its basic premise is that owing to path dependency, farm managers maintain a steady course of minor incremental changes to the farm operation, until an event or opportunity occurs which leads to a decision to actively consider a major change. Then, farmers more actively seek and assess information. New changes are implemented but take time to develop and consolidate, and if unsuccessful, the period of active assessment continues; if successful, the changes become the new norm and farmers become path dependent on using the new innovation.

The paper explores who are the actors who support(ed) farmers throughout the abovementioned innovation cases and their distinctive roles. It also examines the broader conditions and events that triggered and guided adoption processes and highlights the advisory methods used throughout the innovation processes.

Methodology

The study draws data from interviews conducted from April to December 2018 with farmers and regional AKIS-actors involved in the abovementioned innovations. It follows the methodological framework of the AgriLink project, employing a mixed-method approach. Farmer's survey was conducted on the basis of a questionnaire with open and closed questions aiming at gathering both qualitative and quantitative data. A total number of 113 farmers (Table 1) were interviewed based on information provided by key informants: The interviews were recorded, entered in a database and analysed; nine of the interviewees (3 farmers per innovation case - i.e. adopter, non-adopter and one/or dropper where appropriate) were selected to provide an in-depth account (narrative) of their involvement (or not) with the respective innovation. The selection criteria were specific for each case in view of the need to produce a rich picture of the innovation processes. The overall aim was to increase the understanding of the rationale that governed farmers' decision making and the advisory challenges they faced vis-à-vis awareness, assessment and implementation of the innovations.

The AKIS survey addressed 23 advisory suppliers; all identified key actors were interviewed and were asked to suggest other actors engaged in the innovation processes. In the case of Peach Producers' Groups representatives of three private independent advisory organizations (which comprise all the advisory services engaged with the innovation), one public research institute, two cooperatives and four input supply shops were interviewed. For the case of avocado key actors employed in the relevant public service, one public research institute, a nursery, two cooperatives, an input supply shop along with a pensioner academic (with significant contribution and continued presence in the innovation process) were interviewed. For the case of stevia two researchers, the local development agency, and members of the cooperative of stevia were interviewed; additionally, a number of actors/organizations mentioned by the interviewed farmers (a coop/limited company, an input store and a private consultant) were also interviewed aiming at providing insights on the innovation.

Table 1: Farmers interviewed per case study

Innovation case study	Adopters	Non-adopters	Droppers	Total
The implementation of IPM–MD by Peach Producers' in Imathia	25	17	0	42
The dissemination process of avocado in Chania,	27	9	1	37
The introduction of stevia in Karditsa	12	19	3	34

Source: AgriLink – Country Report, Greece

Results

The implementation of IPM- MD by Peach Producers' Groups in Imathia

IPM (Integrated Pest Management) was introduced in Imathia, a region of highly intensive agriculture, by a leading cooperative (A-Coop) that, placing their produce in highly competitive international markets, identified a demand for high quality, certified fruits. This became clear in 1999 owing to a failure in the peach market of the USA, a fact which made the A-Coop to turn to IPM (Vlahos et al., 2017). This event also resulted in the launching of collaboration with an independent advisory company (A-Co) specialised in the implementation of quality systems. The collaboration between the advisory company and the cooperative initiated their search for techniques that would help the cooperative to get rid of the use of pesticides and strengthen its environmental-friendly profile.

In 2001, during a visit to a Research Institute in Italy, the advisor in charge of A-Co became aware of MD; simultaneously he was informed that the Department of Deciduous Fruit Trees of Naoussa (DDFT), Greece, carried out relevant experiments. Along with the A-Coop they decided to test MD locally; however, this proved difficult since the necessary materials (esp. micro sprayers) were not registered and thus were not available in the market while implementation incurred considerable costs as well. The situation changed in 2003 when the advisory company was successful in its proposal for a relevant, three-year pilot project. Thus, in 2004 a small number of peach producers installed a network of micro sprayers across their fields and started implementing MD in close collaboration with A-Co, who were in charge of its implementation monitoring and evaluation.

The promising results of the pilots encouraged two other cooperatives to join the initiative; together with A-Coop they exerted pressure to the Ministry of Rural Development and Food (MRDF) to register the necessary materials. When this was done (2008), the cooperatives decided to subsidize the adoption of the MD up to 50-60 % of its cost through their producer groups' operational programs. In parallel, the cooperatives lobbied at the MRDF for the inclusion of MD in the agri-environmental measures of the National Rural Development programme (NRDP). The attempt was successful; the relevant action, implying the subsidization of MD, was activated in 2014 and resulted in the rapidly increasing dissemination pace of the method by more than 2,000 peach growers, covering 2,800 and 5,500 Ha in 2017 and 2018 respectively.

The very first, few adopters of the method were members of the A-coop Board or friends of them, who shared common interests and were connected with long time, trust relationships. Gradually more farmers were becoming aware of the method as a result of information activities based mainly on their personal interactions with advisors and events jointly organized by the cooperatives and the advisory company as well as through personal contacts with peers The dissemination of the innovation, however, has not been uncomplicated, since many growers, although they recognize MD's potential, are reluctant to adopt the method, since they do not trust that their neighbours will be also involved to the extent necessary for its success. Figures 1-4 depict the actors who influenced farmers by raising their awareness and providing them with advice during the implementation of the innovation as well as the communication/ advisory methods used.

AKIS-actors in Imathia

The advisory landscape of peach production in Imathia comprises a combination of private, public and farmer-based organizations, some of which are activated beyond the local or regional (Prefectural) level (Table 2).

Table 2: The advisory landscape of peach producers in Imathia

Advisory organization	Type of organization- Scale of action
The Department of Deciduous Fruit Trees of Naoussa (DDTN)	Public Research Institute - National
The Directorate of Rural Economy & Veterinary	Public sector- Local (Prefectural)
3 advisory and consultancy companies	Private sector- Local-Regional- National
Individual consultants	Private sector- Local
Input supply shops	Private sector – Local
Cooperatives- Producers' Groups	Farmer-based– Local

Source: Fieldwork, 2018

Fig. 3: Actors, implementation (MD)

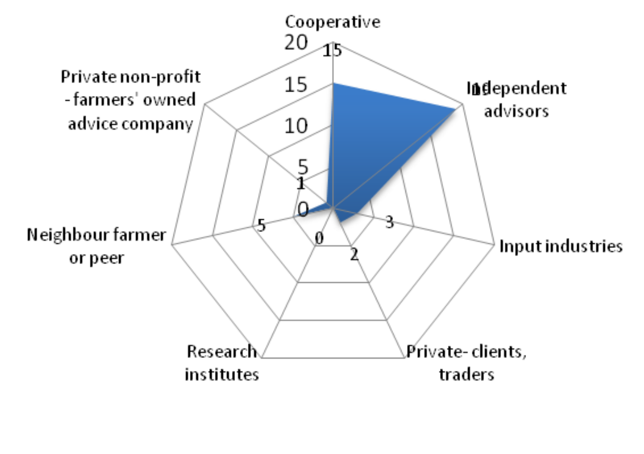


Fig. 4: Communication methods, implementation (MD)

Fig. 1: Actors -Awareness (MD)

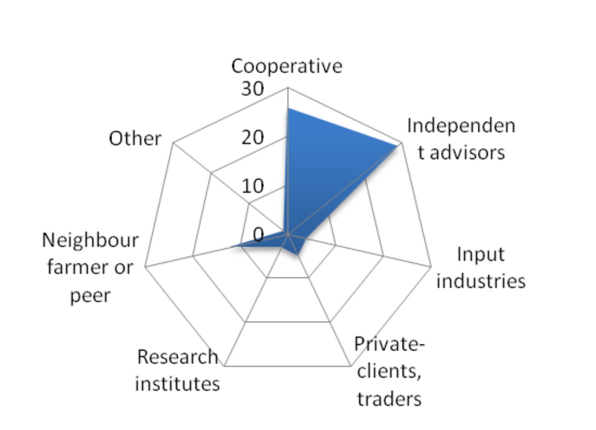
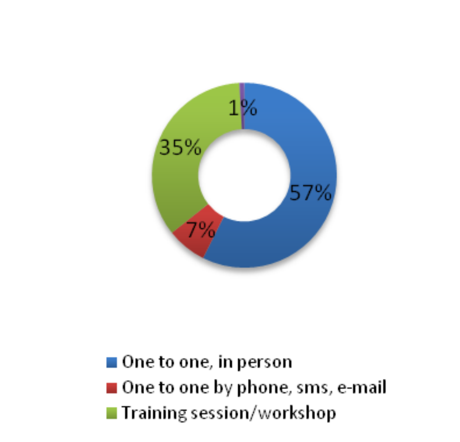


Fig. 2: Communication methods -Awareness (MD)



The dissemination of MD in Imathia owes to the efforts of the A-Co and other local cooperatives that achieved its inclusion in the agri-environmental measures of the NRDP. This event, along with the ‘collegial pressure’ exerted by A-Co, helped the two other independent advisory companies activated in the region and, also, several input supply shops to start supporting the adoption of MD. Nevertheless, A-Co still plays a leading role in all stages of the innovation process. While continuously exchanging opinions and influencing each other, producers may occasionally ask the DDTN as well about the effectiveness of the method.

On the other hand, the aforementioned producers’ reservations, the lack of knowledge and of interest to participate in information/training activities, along with exceptionally adverse weather conditions in 2018 which discouraged new undertakings, make farmers adopt a wait-and-see attitude, which slows down the pace of adoption and prevents positive outcomes from becoming widely visible. In this respect, local actors recognize the all important role of the coops in influencing farmers’ behaviour, including participation in MD training. Moreover, the inclusion of MD in the agri-environmental measures and the relevant subsidy constitutes a strong incentive for adoption, alleviating (some of) these fears.

Finally, it was noticed that the involvement of certain actors in the endorsement of the innovation was poor, especially in the very beginning of the process, and that the links between the local AKIS actors remained weak. But the critical challenge for the advisors involved in the development of the innovation is that the flow of information to farmers remains slow, mainly because the number of advisors activated is not enough to cover needs.

The dissemination process of avocado in Chania

The cultivation of avocado, in the first place, attracted the scientific interest in 1968, when the Research Institute of Olive Tree, Subtropical Plants and Viticulture of Chania established an experimental plantation with avocado. The first adopters who stimulated the interest of other farmers for avocado were an individual producer, who first cultivated and exported avocado in France, and a private company, which tried to establish a commercial avocado plantation but soon abandoned it. In 1985-1995 a project aiming at the wide-spreading of the cultivation, through its subsidization, took place in the framework of the Integrated Mediterranean Programmes (IMP). However, the project did not bear fruits; only 11% of its original target was reached, since olive and citrus growers were reluctant to abandon traditional and profitable cultivations to adopt a new one for which the demand, at the time, was low.

This situation started changing in 2008 due to decreasing/collapsing prices in the olive oil and orange markets and the increasing demand for avocado, globally. This triggered an explosion in demand for locally adapted varieties of high marketability as well as for healthy propagation material. Estimations refer to a rapid expansion of cultivated with avocado areas - especially over the last 3-4 years (80,000-100,000 new trees per year) - expected to cover more than 1,000 ha, in comparison to 450 ha. in 2000. In fact, only farmers who are near retirement, without a successor or farmers whose farm for self-consumption have not been engaged in the cultivation of avocado; the cultivation has been expanded even in marginal fields.

The raising of awareness about and the dissemination of the cultivation of avocado in Chania was a long process involving several private and public actors with peer farmers playing a key role throughout the process (Fig. 5). The most widely used communication method for awareness and assessing the cultivation of avocado was one to one in person contact among the actors involved (Fig. 6). Peer-farmers had a leading role in awareness activities; during the assessment stage the role of researches was strengthened since farmers searched for research evidence to support their decision (and investment). During implementation, local departments of public services and input suppliers emerge as equally important actors. The most valuable sources of knowledge for farmers were discussions with others, their conclusions from running tests and experiments in their farms and their observations on other farms.

Fig. 5: Actors- Awareness (avocado)

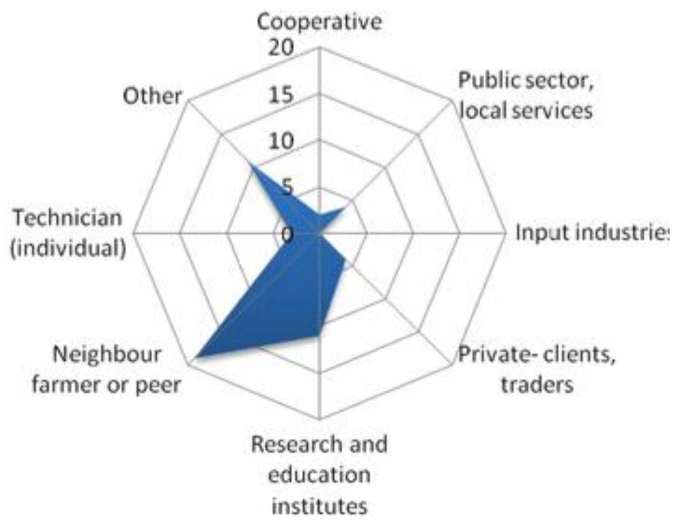


Fig. 6: Communication methods – Awareness (avocado)

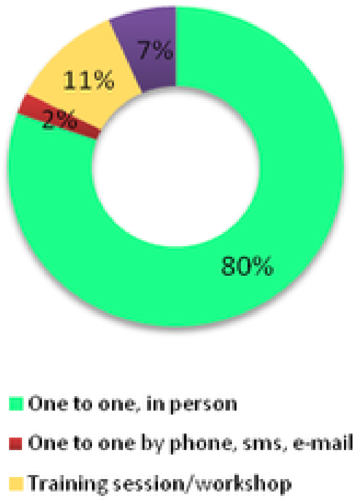


Fig.7: Actors- Implementation (avocado)

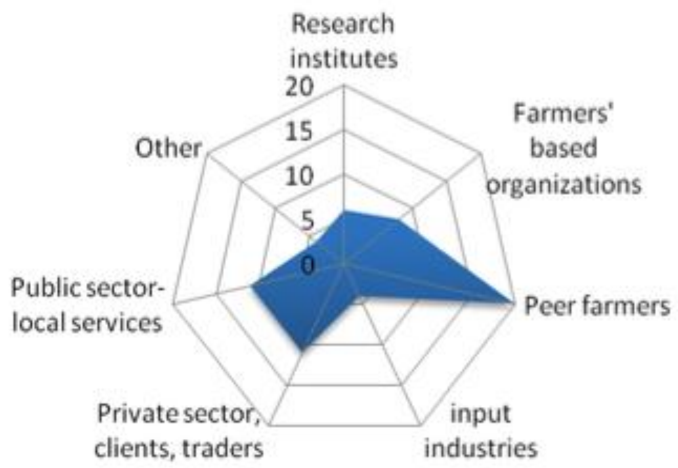
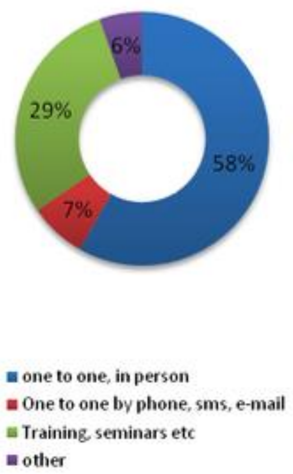


Fig. 8: Advisory methods- assessment (avocado)



Nevertheless, the whole innovation process has been hampered by poor organization and coordination of actions related to the production and dissemination of reliable knowledge (including appropriate propagation material) tailored to farmers' needs; farmers do not consider their interaction with public and private advice suppliers satisfying. Among others, the fact that, on the one hand, public organizations/ services, in general, are not able to provide proper answers to growers' questions as well as that the seminars they organize are not enough to guide growers to find solutions to their problems while, on the other hand, private input retailers are just traders and not reliable advice providers, has been underscored by farmers. Farmers also pointed out that the local agricultural cooperatives fail to support farmers as opposed to some successful cooperatives in the Northern Greece which play a leading role in the exportation of certain agricultural products.

The AKIS-actors in Chania

The advisory landscape of avocado production in Chania is formed by private, public and farmer-based actors/organizations activated at local, regional and/or national level (Table 3); they are also characterized by the fact that their primary mandate is not to provide advice to farmers. Advice is provided mainly on the basis of one-to-one in person communication.

Table 3: The advisory landscape of Chania

Organization	Type/ Scale of action
The Mediterranean Agronomic Institutes of Chania (MAICH)	Intergovernmental organization/ International
Institute of Olive Tree, Subtropical Plants and Viticulture	Public research institute/ National
Directorate of Agricultural Economy and Veterinary	Public organization/ Local
Organic Producers' Cooperative	Farm based organization/ Regional
Agricultural Cooperative of Chania / Orange and avocado producers' group	Farm based organization/ Local
Input supply shops/ Nurseries	Private sector –Local / Local - Regional
Individual consultants	Private sector – Local

The Institute of Olive Tree, Subtropical Plants and Viticulture of Chania was the critical player triggering the initiation and the dissemination of the innovation for more than a decade, resolutely affecting the decision of the first adopters, partly due to the efforts of its director who was a well-respected and influential actor locally. Nevertheless, some of these early adopters soon found themselves dealing with severe cultivation and marketability problems and some of them started decreasing or abandoning the cultivation. In parallel, the Institute gradually stopped playing its leading role due to administrative problems. However, its impact is still evident since the majority of the nursery owners and researchers who played a key role in the dissemination of avocado the subsequent years had, earlier, collaborated with the Institute. Recently though, the situation in the Institute started changing as new scientific staff, willing to collaborate and support avocado producers, has been recruited.

In this framework, a scientist of the Institute participates in an informal working group along with three other agronomists employed in the local Directorate of Agricultural Economy and Veterinary Service, the local Organic Producer's Cooperative, and MAICH as well as a retired academic who has been providing advice to avocado producers since 1970s, when he started collaborating with the Institute as a young researcher. This group aims at supporting avocado growers by putting forward project proposals, which the regional government is invited to accept and realize. Their cooperation includes regular meetings on a voluntarily basis and the organization of information events and training for farmers.

The abovementioned actors recognize the importance of establishing permanent communication channels with farmers. They also point to the significance of peer–to-peer exchanges among producers but also highlight that, these exchanges often result in the perpetuation of false cultivation practices. In addition, they agree that this communication behavior accelerates the dissemination of avocado but they attribute the rapid expansion of the cultivation mainly to the worsening conditions in the citrus and olive oil markets.

The introduction of the cultivation of stevia in Karditsa

The introduction of stevia in the Prefecture of Karditsa was based on the results of research programs co-funded by the EU aiming at alleviating the severe competitiveness problems of traditional crops such as tobacco, cotton and sugar beet. Searching for alternative crops, two public research institutes -the Tobacco Research Centre and the University of Thessaly- carried out experimental fields with stevia and concluded that it is well adapted in several areas throughout the country, including the Prefecture of Karditsa. The outcomes of these projects were disseminated through the press and seminars targeting specific groups of farmers.

In 2012, a local group in Karditsa Prefecture took the initiative to organize such a seminar. This group, named Fanariotes, originating from the local community of Fanari, was active in calling experts to provide information on topics of interest to local farmers. They invited two academic researchers from the University of Thessaly and the Technological Education Institute (TEI) of Larissa as key speakers, who provided information on stevia cultivation practices and a new experimental method for the production of steviol glucosides, respectively. During the seminar participants also became aware of a preliminary market assessment showing a growing interest for stevia in the international markets. The fact that the academic from TEI could make the processing method freely available to farmers convinced some of them to establish a cooperative engaged in the cultivation, processing and trading of stevia (ASYST), aiming at the vertical integration of the production chain through the establishment of a processing unit. The cooperative was established by 21 farmers and its membership increased over time to 64 (Koutsouris and Zarokosta, 2018). During the next cultivation period the cooperative run pilot fields, under the guidance of the University professor; the following cultivation period the farmers, acting on their own, imported seeds from Paraguay and Spain and started establishing their stevia plantations.

Raising awareness for stevia among Karditsa farmers was the result of the abovementioned seminar with the two researchers stimulating the interest of farmers; some of them had already been in a process of thinking about changes and recognized stevia as an opportunity to increase their income. In the following years awareness activities were undertaken by ASYST members on the basis of one to one in person interaction or through workshops and group discussions (Fig. 9-10).

The assessment process for most of the adopters was triggered during the seminar and continued during the subsequent cultivation period, when they run pilot fields; members of ASYST attended seminars delivered in the University of Thessaly, while the University professor visited some farms and suggested cultivation practices to farmers (Fig 11). Then the farmers disseminated the knowledge they gained to their colleagues through discussions and visits to the pilot farms (Fig. 12). Some farmers also sought information from a company engaged in the production and trading of aromatic and medicinal plants and stevia in another region; additionally, some looked for information from the input suppliers they collaborate with but none of them could advise them since stevia was unknown to them. During assessment the main motivation for adoption concerned the prospect of profits related to the potential operation of the processing unit. On the contrary, factors of non-adoption included financial constrains since farmers' involvement entailed the financing of the processing unit; uncertainty as regards the efficiency of the experimental processing method to produce products of the expected quality along with the lack of an alternative marketing plan; lack of advice on cultivation issues and worries of loss of income were also important.

During the implementation process ASYST farmers collaborated closely, organizing discussions, paying farm visits and exchanging valuable knowledge. The main challenges they had to overcome were related to the supply and the treatment of seeds and planting material as well as to the drying process requiring special and very expensive facilities.

Though ASYST managed to build an environment conducive to interaction and learning, at least two of its members abandoned the cultivation since the cooperative stopped collecting stevia leaves, after failing to get the processing unit into operation, and the lack of an alternative plan of placing the produce in the market. This reason is also referred to by half of the non-adopters as the main reason of their decision; other reasons concern the lack of know-how and support on cultivation issues, uncertainty as the innovation is at an experimental stage and financial restrictions given the high investment cost of the processing unit. Nevertheless, droppers intend to be involved again in the cultivation of stevia, in case the problem with the processing unit is solved.

Fig. 9: Actors- Awareness (stevia)

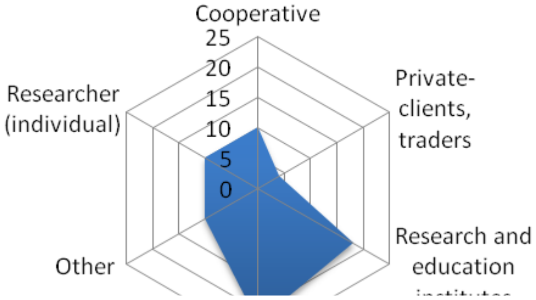


Fig. 10: Communication methods- Awareness (stevia)

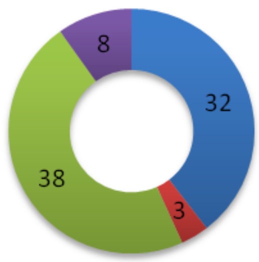


Fig. 11: Actors - assessment (stevia)

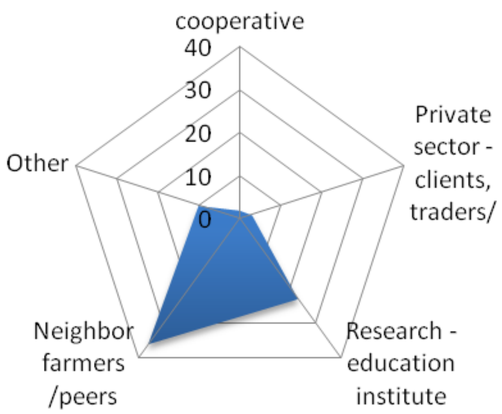
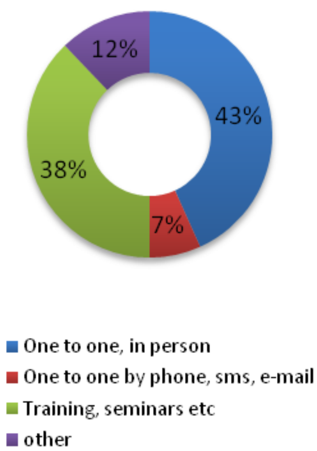


Fig. 12: Advisory methods, assessment (stevia)



The AKIS-actors in Karditsa

The key players in the case of stevia were mainly the abovementioned two researchers as well as the stevia cooperative (ASYST) and its members. However, the advisory landscape also includes actors who played a secondary but important role in the initiation of the innovation such as the local group of Fanariotes and the Development Agency of Karditsa providing consultation mainly concerning the establishment of ASYST.

All external advice suppliers were activated only during the awareness and assessing stages, while ASYST supported the implementation of the innovation through interactive activities among its membership. ASYST's practice not to seek continuous support for cultivation issues from a knowledgeable scientific partner was criticized by some AKIS actors and non-adopters, claiming that ASYST underestimated the need for scientific knowledge.

Conclusion

Given the weak and fragmented AKIS, notably the demise of public extension, in Greece, this paper explores the existence (or absence) and the roles of advisors/supporters in three innovation cases. In the case of MD the leading independent advice supplier, though it developed some intermediary activities, was confined to the traditional extension paradigm, creating awareness among farmers for a technical innovation and bridging the gap between researchers and farmers. On the contrary, the cases of avocado and stevia were characterized by the absence of provision of extension services; instead various actors (agronomists, researchers, input sellers as well as individual farmers or/and farmers' organizations) tried to support and influence, to varying degrees, farmers' decisions making processes.

The advisory landscape in the three regions varied significantly as well. In Imathia the collaboration between a cooperative and an independent advice company created conducive conditions for the adoption of MD, became an example to follow for other cooperatives and independent companies and, thus, contributed to a more structured support environment in comparison to the two other cases. In Chania the advisory landscape was muddled; various actors tried to support avocado growers and enhance knowledge with dubious results. Avocado growers relied at large on peer-to-peer exchanges throughout the innovation process. The main collective activity of the key advice suppliers was their engagement in an informal working group aiming at promoting proposals, which the regional government was called to endorse; however, this activity did not yet produce significant results. In Karditsa, the stevia cooperative was involved in experimental/experiential activities that enhanced its members' knowledge and ability to interact with each other. Nevertheless, the fact that all activities were confined within the cooperative did not allow for the creation of space for the development of interactions and synergies with other actors and, consequently, did not generate changes in the advisory landscape.

Advice suppliers in all cases identified farmers as valuable sources of knowledge; this indicates a possibility for co-creation of knowledge. Moreover, peer-to-peer interaction is a widespread practice among farmers; this also occurs among advisors in Imathia and, to some extent, in Chania. However, important structures and capabilities for co-creation and synergies seem to be lacking.

Therefore, amidst a national AKIS which is weak and fragmented, in all the innovation cases examined here it is quite obvious that the links among the local AKIS actors, despite some efforts for synergies, are also weak; this, in combination with a lack of research tailored to farmers' needs, affects all existing advisors'/supporters' ability to obtain and disseminate knowledge and advice farmers effectively and efficiently. Moreover, both farmers and advice suppliers admitted, to different degrees, dissatisfaction with the provided advice services, with advice suppliers highlighting the lack of staff, necessary data and tools facilitating advisory work.

Such findings, on the one hand, verify and, on the other hand, complement previous research concerning the provision of extension/advisory services in Greece. Especially the use of the notions of micro-AKIS and R-FAS prove extremely useful in disentangling the extension/advisory landscape at local level with reference to specific innovations. In the case of Greece examined here, the macro picture of the national AKIS as well as surveys addressing farmers' (dis)satisfaction from current extension/advisory (including training) services become now 'clearer' as we have been able to identify exactly who supports -and in what way- innovative endeavours in the Greek countryside. So the overall dysfunctional picture of the Greek AKIS is now complemented with (somewhat) positive experiences which nevertheless, due to the gaps identified at micro-level as well, also point to the urgent need for a clear, integrated and stable policy mix aiming at (a) bridging the gap owed to the fragmentation of extension providers through the setting up of networks to support learning and collaboration among diverse providers at both regional and national level and (b) the building of Innovation Platforms (see: Magala et al., 2019) and, finally, of a functional national AKIS. Policy should focus both on creating more space for potential innovators and facilitating the establishment of stable linkages among the potentially involved actors. Nevertheless, though there is abundant of international literature on the role of innovation brokers facilitating innovation processes in various fields, certain actions facilitating their emergence within a weak institutional environment are not obvious and, in particular, not easily performed. Successful innovation brokerage presupposes knowledge and competencies on the part of individuals and organizations willing to play this role (Ward et al. 2009; CHSRF, 2003; Robeson et al. 2008). Moreover, the actors engaged in innovation initiatives should understand and accept brokers' function; but such conditions are not evident in the examined cases, therefore, they should be created by a variety of measures (such as specific projects and Living Labs) aiming at building capacities and changing mindsets at national, regional and local level.

The further elaboration of the current preliminary results (possibly with the use of Social Network Analysis tools) in which additional data can be included (as for example the sources of knowledge of the advisors/innovation supporters; see Zarokosta and Koutsouris, 2019) may yield further interesting results.

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THE ROLE OF ADVISORY SERVICES IN THE UPTAKE OF SMART FARMING TECHNOLOGIES: EVIDENCE FROM FIVE EU COUNTRIES

Leanne Townsend [a], Christina Noble [b], Marta Mrnustik Konečná [c], Gunn-Turid Kvam [d], Lívia Madureira [e], Noemie Bechtet [f], Pierre Labarthe [g].

[a], [b] James Hutton Institute, UK
[c] Institute of Agricultural Economics and Information
[d] Ruralis – Institute for Rural and Regional Research, Norway
[e] University of Trás-os-Montes e Alto Douro (UTAD), Portugal
[f], [g] National Institute for Agricultural Research (INRA), France

Abstract

Smart farming technologies (SFTs) such as variable rate precision farming, milking robots and smart sensors can lead to better productivity, yields and cost savings as well as supporting more environmentally sustainable farming practices. Despite these advantages and the growing prevalence of SFTs, patterns of adoption vary within regions and across European countries. This is in part due to characteristics of specific farms such as farm size and type, as well as changing advisory landscapes with services becoming more fragmented, and challenges for advisors and policy makers in keeping up to speed with technological developments and the changing structures of farms.

In this paper we present findings from five case studies (UK, Czech Republic, France, Portugal and Norway) exploring the role of advisors in the uptake of SFTs. We discuss the factors affecting adoption of SFTs. We focus on the role of microAKIS on decision making in innovation adoption. Finally we reflect on the implications of these findings on the future roles of advisory services in relation to supporting farmers' decision making in relation to SFTs.

Introduction

Agriculture in Europe is becoming an increasingly digitised sector. Smart farming technologies (SFTs) aimed at improving farming practices are being developed at a rapid pace. These developments are heralded as having the potential to alleviate the economic, ecological and social challenges associated with modern agriculture, resulting in more sustainable farming across Europe (Kernicker et al. 2019). Increasingly popular SFTs include variable rate precision farming, milking robots and smart sensors (e.g. the "Internet of Underground Things" - Vuran et al. 2018). These and other SFTs are argued to revolutionise agriculture, in many cases already leading to better productivity, yields and cost savings as well as more environmentally sustainable farming practices (Rose and Chilvers 2018). On the other hand, digitalisation of farming practices enables further industrialisation of agriculture (Wolf and Buttel 1996) exacerbating existing inequalities between agricultural stakeholders. Nonetheless, it can be argued that farms have much to gain by embracing the digital age and engaging with tools for more efficient and profitable food production.

Despite the promised benefits, patterns of adoption vary across European countries. This is in part due to characteristics such as farm size and type. It has been argued that SFTs are most often adopted by larger farms because these are better placed to benefit from technological advancements (Kernecker et al. 2019). In addition, advisory knowledge and innovation systems (AKIS) for farmers vary from country to country. In this paper, we conceptualise the range of individuals and organisations that farmers seek and exchange knowledge from as "microAKIS" (Labarthe et al, 2018). In Europe, advisory landscapes are becoming more fragmented, and challenges arise for advisors in staying abreast of technological developments as well as keeping up with the changing structures of farms.

"AgriLink"[4] is a Horizon 2020 project which seeks to understand the roles of a wide range of advisory organisations (microAKIS) in farmer decision-making on the uptake of various innovations across Europe. The project works across 13 partner countries and eight innovation areas. The innovation cluster of relevance to this paper is **"Autonomous vehicles, robots, drones, intelligent sensors and precision farming", in which case studies were carried out across five European countries -** Czech Republic, France, Norway, Portugal and UK.

In this paper we present findings from the case studies. In Section 2 we present our literature review. We outline the changing nature of AKIS in the different EU countries (2.1), discuss the factors affecting adoption of SFTs (2.2) and consider the role of microAKIS across the various stages of decision making in SFT adoption (2.3). In Section 3 we present our research methodology. In Section 4 we present our results and discussion. Section 5 presents our concluding remarks.

Technological innovations, adoption on farms and the role of microAKIS.

Section 2 outlines the literature in terms of changing advisory landscapes, technology adoption on farms, and the role of microAKIS in supporting that adoption.

Changing advisory landscapes

Advisory landscapes are undergoing transformation across Europe (Kania et al. 2014). There exist various drivers behind these changes, for example the commercialisation and privatisation of services (Prager et al. 2016), and new technological developments (Knierim et al. 2017). Research shows that these drivers have resulted in fragmentation of advisory services in different EU states, and have impacted on the capabilities of advisory services to support farmer decision making in a number of innovation areas (Labarthe et al. 2018).

In the UK, the late 20th century marked significant changes for farm advisory services (FAS), as previously state-funded advisory organisations were commercialised and then privatised (Prager & Thomson 2014). A fragmentary sector resulted in specific challenges, namely the increase and diversity of other actors including NGOs and private commercial companies to provide advisory services. FAS is considered to be a devolved power and is contracted out to different organisations with each nation having their own rural development program and specific areas of interest to be targeted.

In France, Agricultural Chambers were the main actors of the FAS. They were created by the State after World War II with the objective of modernising French Agriculture. The Chambers oversee agricultural extension (Brives, 2008) and are organised at the local level. However, they are challenged by other advisory organisations, trade organisations and Farmer Based Organisations (FBO). With the progressive decline of public funding, the Chambers reorganised their activities towards paid advice and services (Labarthe et al, 2013). Today French FAS is dominated by large farmer cooperatives that are dealing with commercial contracts, selling inputs and offering free advice to farmers.

In Norway there has been a transformation towards privatisation and paid services in recent years (Klerkx et al. 2017). The earlier public and free advisory service does not exist anymore and the cooperatives are the main advisory actors. The only independent actor is the Norwegian

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Agricultural Extension Service (NAES); other actors are input or output cooperatives in agriculture. The transformation has resulted in more competition and less cooperation between advisory organisations (Kvam and Stræte 2018).

In the Czech Republic, during the late 20th century and the end of the communist regime, FAS, which had previously been state-funded, were commercialised and then privatised (Ksouda et al. 2016). The new advisory services helped newly privatised farms to consolidate their property bases and adapt to market management systems, offering advice on subsidies and compliance with government regulations (Pulkrábek & Pazderu, 2014). The market environment and press to modernisation have opened the door for strong players from technology and inputs suppliers as well as facilitators from FBO. The influence of suppliers is even stronger because farmers are not willing to pay for advice. Thus advice is integrated into product sales.

In Portugal, FAS builds on a large number of regional and sectoral FBOs comprising farmers' associations, cooperatives, and producer's organisations. It is overall a weak and fragmented FAS, although innovative FBOs have emerged since Portugal's entrance into the European Economic Community. These FBOs sell inputs, equipment and technical advice to farmers. Local governments are emerging as a relevant AKIS actor in some regions, by supporting the FBOs. Private independent advisors have emerged, although these are more focused on specific topics and targets, such as project development or book-keeping services.

2.2 Technology adoption on farms

Agriculture is experiencing a global technological revolution, increasingly refered to as the "Fourth Industrial Revolution", or "Agriculture 4.0" (Rose and Chilvers 2018). SFTs are lauded as transformative for the economic, environmental and social challenges of modern agriculture (Kernicker et al. 2019). New technologies are accompanied by promises of a more sustainable future for agriculture, in terms of food security and even smart responses to climate change (Long et al 2016). The role of SFTs is therefore high on the worldwide political agenda (El Bilali and Allahyari 2018).

However, the adoption and diffusion of SFTs on farms across Europe has been slow (Long et al. 2016). There are a number of reasons including complexity of SFT systems (Eastwood et al. 2017) as well as characteristics of farms which can act as barriers to adoption. SFTs are most likely to be adopted by larger farms better placed to benefit from technological advancements in agriculture (Kernecker et al. 2019). Many SFTs entail costly investments. Small farms are unlikely to have the financial resources to invest in SFTs, and the small scale of their operations means that returns on investments takes longer.

SFTs also contribute to an increasingly mechanised sector with farms operating on much larger scales. Small farms face increasing marginalisation as many SFTs are not well adapted to small scale farming practices (Wegren 2018). Hence whilst large farms enjoy the benefits of the digital economy, smaller farms are left behind and suffer competitive disadvantages and increased marginalisation (Wegren 2018). These are the elements of the *agricultural digital divide* characterised by both winners and losers in an increasingly high-tech agricultural sector (Hennessy et al. 2016).

The role of microAKIS in supporting the uptake of SFTs

Research has found that diffusion of SFTs is hindered by a lack of appropriate support, particularly where technological systems are complex, and that collaboration between different stakeholders and support organisations is required in order to support future uptake (Eastwood et al. 2017).

Unfortunately, the capabilities of advisory services to support farmer decision-making are stretched, as we outline in Section 2.1, but especially in regard to innovations and new technology (Labarthe et al. 2018). As we show in Section 4, the adoption of SFTs is not only supported by traditional advisory services in all of the five countries; instead, new players in these microAKIS are becoming more prominent. Our research explores the extent to which there is still a role for traditional advisory services in the uptake of SFTs on farms in Europe; or conversely, whether these roles are increasingly adopted by commercial companies which better understand the technological landscape of SFTs.

Methodology

Case studies were carried out in five European countries (Czech Republic, France, Norway, Portugal and UK) between 2018 and 2019. In-depth semi-structured interviews with more than 200 farmers (characterised as adopters, non-adopters and droppers of specific technologies) and with advisors and AKIS experts explored the role of advisors in supporting uptake of SFTs (see Table 1 for the range of technologies in question). We consider adopters of a technology as those who used the technology on their farm during the year of the study. Non adopters are farmers who never used the technology on their farm. Droppers are farmers who have used the technology during the past but no longer do. Some case studies also use the category of "partial droppers" to refer to farmers who drop certain applications but not the entire technology.

Farmers and AKIS experts in the study were identified through snowball sampling, and by sending letters out to farms and advisory organisations identified through local business directories and local farming fairs. Farmers were interviewed at their own farms. The in-depth interviews posed a number of questions relating to the adoption (or non adoption, or dropping) of the technology in question, and the role of various advisors and other actors in a) becoming aware of a technology, b) assessing its potential impact on the farm, and c) implementing the technology on the farm.

Data was analysed using Nvivo which allows for the coding of qualitative data into a thematic framework for analysis. Results are presented below.

Results and Discussion

Table 1 presents an overview of the contrasting findings across the five countries.

Table 1: Overview of findings in the five countries

Country	Technology	Advisors	Adopter characteristics
UK	Variable rate precision farming via soil sampling	Mostly private – chemical input companies	Larger farms more likely to adopt – arable
Czech	Variable rate precision farming via satellite and soil sampling	Mostly private – chemical input companies and machinery suppliers. Also pioneer farmers.	Larger farms are more likely to adopt – several farms owned by large corporations. Arable crops.

France	Variable rate precision farming via satellite and drones	Cooperatives (that are selling the service via a tech company). Also Fmachinery suppliers, and traditional advisors who attempt to re-enter market via precision farming.	Diversified, mixed (arable and livestock). Larger farms not more likely to adopt.
Norway	Automatic milking systems (milking robots)	Machinery advisors advise on the hardware (machines) whereas the Dairy cooperative advises on the software. The cooperative are not public but a more traditional form of advisory service.	Large farms more likely to adopt, smaller farms must rent more land, in order to produce more fodder for more cows (because it is not cost efficient to invest in the tech if not enough cows)
Portugal	Irrigation sensors (moisture probes).	Regional advisors association (cooperative). They both sell the farmers' products and also sell inputs and advice to farmers. Collaborate with hi-tech companies.	Larger farms with larger plots (and less plots) more likely to adopt.

The UK case study was focused on *variable rate precision farming technologies* (VRPF). The UK case study was carried out in North East Scotland, encompassing the Aberdeenshire and Angus regions. 31 farmers and 6 advisory suppliers were interviewed. Of the farmers, 22 were adopters, 6 were non adopters and 3 had dropped only part of the technology. The total agricultural land for all the farmers in this case study amounted to 17,512 ha, with the average farm size being 565 ha. Despite this high number, the majority of farms, nearly 75%, held agricultural land under 500 ha.

The UK findings highlight that advice on SFTs is increasingly provided outside of traditional advisory organisations. Advice on the adoption of VRPF was most commonly being provided by two private commerical companies dealing in machinery and chemical sales. One of the AKIS experts indicated the traditional advisors in the region are not considered the best source of advice regarding these types of SFTs, instead they turn to private companies who have more expertise in these technologies on farms. FAS are instead associated with support with administrative or legislative matters:

"*You want to find out about new or innovative ways of crop production, you go to [private company specialising in soil sampling] or the Internet or whatever. So, you know, and that's quite sad and it's slightly worrying for the industry."* (AKIS expert).

FAS within the region are increasingly associated with legislation compliance, and not with technological advances. This highlights a growing gap in expertise relating to FAS and new technologies.

Of the commercial companies providing advice on how (and whether) to implement SFTs, farmers tended to name trusted individuals. Many farmers reflected working relationships with individuals which span many years. These are trusted relationships, in some cases built over multiple generations on the farm. The companies themselves have in many cases evolved over decades to respond to technological advancements – hence they have developed (or brought in) expertise in new technologies to remain competetive in terms of the provision of farming services and products.

For uptake of all VRPF technologies, farmers were typically requesting (or being offered) a soil map, produced by commercial companies specialising in soil sampling, by taking samples at regular intervals across a field. The output of this map is both visual (a colour coded map that can be printed or viewed on a screen) and a data file which is compatible with certain software (or apps) which work with precision farming equipment on the tractor (the hardware). The tractor receives information about how much inputs to apply at various places in the field. This represents a large potential cost saving on inputs, because traditional farming applies the same level of inputs across all parts of the field, whether they are needed or not.

"I knew my fields were not homogeneous but after I received the output [the soil sample maps] from the supplier I was surprised how the soil condition of some of the fields were variable" (farmer).

It is this soil map that has proved to be a very influential trigger on adoption. Farmers, on seeing this map, immediately recognise the potential cost savings (through reducing inputs) of adopting VRPF.

It is not only the initial uptake of VRPF that requires advice and support, but also the ongoing use of the technologies. As one farmer stated:

"It's what you do with that information once you've gathered it and how you then regurgitate it and then use it the following year or the following season or whatever. And I think that's probably where the challenge is." (Farmer).

In this regard, traditional FAS are again not seen as expert enough to provide support, hence farmers prefer to maintain relationships with individuals within those commercial companies providing advice on the technologies. The challenge for FAS will be to adapt to constantly advancing technologies and their applications, and the use and storing of data for benefits on the farm, when others who are closer to the technologies are better equipped to respond to these advances.

The Czech case study looked at VRPF in two regions - South Moravian and Central Bohemian region. 35 interviews with farmers and 8 interviews advisory experts were carried out. The sample was composed of 19 adopters, 15 non-adopters and 1 dropper.

The total area of farms covered in the Czech case study is 54,100 ha. The average area in the case study is 1,546 ha.

The adoption of VRPF varied according to the size of farm and farming focus. The consideration of adoption was based on several parameters such as existing use of GPS and the level of accuracy required during farming. Thanks to the post-communist (cooperative scheme) field arrangement, i.e. farms with typically big fields (more than 30 ha per plot), Czech fields have high potential to take advantage of this innovation. Larger farms access very high accuracy navigation mainly through RTK (Real Time Kinematic) correction, where stationary stations correct the inaccuracy of the moving satellites by up to 2 cm. The huge initial investment is quickly returned through cost savings on inputs used across the large scale of these farms. Besides VRFT, some innovative large farms experimented with belt sowing of two different crops targeted to the erosion-risk fields.

"The state regulation of soil protection pushes us to experiment with new ways of farming in our large fields." (Agronomist of a big farm)

The smaller farms invested in the cheaper but less accurate variation of navigation through the paid satellite service which allows accuracy up to 5 cm, or through a free satellite service which allows accuracy up to 25 cm. This insight garnered from this approach are usually combined with soil sampling and the local field knowledge of the farmer.

"I do not need to have GPS with high accuracy, I know my fields and the soil sampling of a particular grid of the field is sufficient for suitable applications." (small-scale farmer).

Interviews in both regions illustrate the importance of informal learning. Reciprocal services between the suppliers of advice and farmers are crucial. Despite the demanding transition process, we found that trust tends to grow following a previous good experience. Machinery and input suppliers know the importance of reciprocity; therefore, they willingly support farmers with ongoing information and services. Czech farmers are not used to paying for advice, it therefore has to be covered through the cost of other items, inputs or services. Mutual knowledge sharing and cooperating are also growing between farmers. Therefore, in the last few years, well-experienced farmers have become very important providers of advice for other farmers. The role of the farmer-based organisations is also significant, mainly as a bridge between farmers and other relevant actors (researchers, specialists, policy-makers) in the awareness stage.

In summary, in the Czech Republic case, the main suppliers of advice on VRPF are private companies such as machinery and input suppliers as well as pioneer farmers – there is little role for traditional advisors in this sphere, given they have less expertise in this field.

The French case study relates to crop input modulation tools for fertilisation, with a focus on tools using drones and satellites. The study was conducted in the South West of France, in the Gers region. 33 farmers were interviewed. The sample consisted of 19 adopters, 8 non adopters and 6 droppers. We also interviewed 19 advisory experts: 6 advisors, 2 machinery dealers and 7 private companies in relation to VRPF.

All farms (except 1) are established family farms. Many farms still follow a diversification strategy with activities other than growing crops. About one third of farms (36.5%) still own animals (duck, poultry, bovine). The total agricultural land for all farmers in this case study amounted to 6,101 ha, with the average farm size being 150 ha.

The adoption of SFTs is strongly linked with the main advisory organisations already established in the region. Farmers are already aware of the existence of the technologies but their advisor has a key role in transforming awareness into the adoption. Advisors trigger the adoption of SFTs by offering farmers various technology services. The service often originates from a start-up or other external company outside the advisory organisation: advisors are reselling the service.This offer is made during one of the regular visits made by the advisor to the farm. In the French sample, all farmers who received such an offer quickly accepted it. Farmers often justify this quick decision by citing the trusted relationship they have with their advisor:

"This [name of the cooperative] I had been working with them for 10 years. It was [name of the advisor] who came, who was my technician and who told me "Would you like to start with us, it's not about using inputs, but we're going to use satellites". (Farmer).

Farmers who are already well connected with advisory organisations (typically members or former members of farmers' unions or cooperative boards) are more likely to receive the proposition to adopt SFTs. In this sample, farmers who did not adopt the technologies were farmers who had weaker connections with their advisors and therefore never received any offer from them. However, although traditional advisors are key actors in trigerring adoption, farmers implement the innovation independently and rarely discuss with their advisors the crop input modulation maps generated by the technological tool they bought, because these aspects are beyond the traditional skillsets of advisors. The main difficulties are linked with machines and connectivity:

“We solved the problem at the [name of of a local fair on farming innovations] where I had gathered [name of the advisor], the guy from [name of the start-up developing the technology], the console builder, the distributor builder, the farm contractor and me. There were six of us! I want a conclusion: why didn't it work? The device did not work. [Name of the tractor brand] couldn't read the maps. […] In fact there was a position A and B and it had to be put on B and nobody knew.” (Farmer).

Thus, advisors are key actors in the dissemination of SFTs at the local level. The challenge for them will be to reassure their role and legitimacy with respect to other actors, especially the developers of SFTs (software) and machinary dealers (hardware) who are often better equipped to deal with technological challenges faced by farmers.

The Norwegian case study considered automated milking systems (AMS). The case study was carried out in the county of Trøndelag, located in the middle of Norway. Altogether 29 farmers were interviewed, including 20 adopters and 9 non-adopters. It is very rare that dairy farmers remove AMS after installation: therefore it was not possible to find any droppers. Additionally, we carried out interviews with eight AKIS experts. Sampling of these experts was based on the interviews with farmers.

Results from the study shows that size is important for implementing a milking robot both regarding number of cows and area of arable land. Most farmers had between 20 and 60 dairy cows. The non-adopters had 60 cows as a maximum, while adopters had up to 100 cows. The majority of the sample have 41-80 ha. We find that installing a milking robot increases the need for more cows, buying milk quotas and renting or buying more land – therefore illustrating structural consequences for farming in Norway.

Management of dairy farming is partly based on data and tools related to the Norwegian Dairy Herd Recording System (NDHRS) operated by the milk cooperative, Tine. Milking robots are associated with increased efficiency and productivity, and consequently profitability in dairy farming as well as more flexible working conditions for dairy farmers and their households. For farmers and advisors, it was other farmers and suppliers of AMS, rather than traditional advisors, who were most important in raising awareness of the innovation. Advisors and AKIS actors are more active in helping farmers to assess the potential benefits of implementing the innovation. At this stage, the farmer needs several kinds of information in order to make decisions for his/her future farm. The milk cooperative Tine, the Norwegian agriculture extensions service (NAES), the technology companies and their Norwegian suppliers are all important advisors. Tine and the input providers have bigger roles than traditional advisors in this phase, because they have developed specialised startup advisory services focused on technology regarding different milking robots. Tine has advisors specialised in the most common robots, in addition to specialised advisory service on feeding, milk production and breeding related to dairy production with milking robots.

Due to the extent of adoption of AMS in Trøndelag, changes in the advisory landscape have emerged. Input suppliers are primarily salespeople but are used by farmers as advisors. These salespersons have a double role, and act as advisors on the adoption and implementation of AMS because they have first-hand knowledge about the technology.

“I am not sure that the traditional advisers will manage to keep up with the future technological development. We (suppliers) are the most updated on the technology and the farmers have increasing requirements for expertise in the field”. (Supplier).

Traditional advisors struggle to keep up with farmers’ needs for specialised advice. The farmers have gained so much knowledge that they may have more knowledge than the advisors in some cases. The traditional advisory services acknowledge that they have challenges in keeping up with technological developments. They see the need for the different actors, including their competitors, to collaborate in order to meet the farmers' needs for specialised advice on AMS. The suppliers also see the need for more collaboration between the different actors in order to coordinate their advice to provide farmers with the "whole package" at various stages of adoption, rather than fragmented information.

In Portugal the selected case study focused on the adoption smart irrigation sensors (moisture probes). The group of farmers comprised commercial small, medium and large growing irrigated crops in the river Tagus flatlands region, known as Lezíria do Tejo (NUTS 3). It is an agrarian predominantly rural area close to city. It comprises medium sizes cities and is nearby the Lisbon conurbation. Irrigated crops predominated in this region, mainly maize and vegetables, and tomato for industry. The interviews were administrated to a sample of 38 farmers, 21 currently adopters, 10 non-adopters and 7 droppers. Farmers in this region have a similar business model by producing and bulk selling their production to large assemblers, such as cooperatives or the industry, although some larger farmer negotiate directly with the private agro-industry and the large distribution.

The Portuguese case study took place in the Lezíria do Tejo region. The crops produced in this region are mostly vegetables (including onions, sprouts, cabbage, broccoli and pumpkins). The average farm size across the sample is 177 ha, with adopters having larger farms (average 225 ha) compared with non-adopters (average 35 ha). There were 38 farmers interviewed (21 adopters, 10 non adopters and 7 droppers) as well as 4 AKIS experts.

The regional AKIS is characterised by a strong presence of suppliers of inputs, equipment and technologies. All of these actors are involved in providing advice on the innovation, although it was first introduced to farmers by an FBO (a regional farmers' association). The association first introduced and tested the probes in the region in 1998. In 2008, once the smart probes became commercially available, they were disseminated and developed by the FBO, which has since worked closely with high technology developers developing software for the probes:

"FBO Agromais are designing differentiated actions to enhance farmers active use of the information... in partnership with the hi-tech company". (FBO advisor).

This a case where advisors (FBOs) played a key role in the introduction and development of the innovation, by working with the hi-tech sector in the design and supply of the technology. Currently, probes are supplied by a number of manufacturers but the software to operate them is developed and released by a few high-tech companies that work informally together with the FBO referred to above.

Probes are installed in the soil and monitor parameters such as humidity, temperature and salinity at different soil depths. This allows farmers to know when and how much water is needed to irrigate their fields. The data obtained from the probes can be directly used by farmers installing the app on their mobile phones or other electronic devices. However, we found that most of the adopters rely on information "ready-made" by the FBO that analyses and interprets data from the probes alongside meteorological information. Only a very few adopters are active users of all aspects of the technology. Non-adoption and dropping is mainly related to unsatisfactory returns on investment. Lots of farmers have land scattered over many small plots, making the cost of having at least one probe for each plot unfeasible. The probes are typically leased for an annual fee by the FBOs, who in turn provide farmers direct advice along with support on irrigation systems and the supply of inputs and irrigation equipment. In general farmers appear to have a positive view of the probes although their economic benefits (the energy savings) are only fully realised by a few intensive users of the probes.

This case study shows that traditional advisory services can play a role in SFT adoption if they are knowledgeable about the technology's development and use. This entails effective collaboration with high-tech companies and working closely with farmers in order to support them in the adoption and ongoing use of the innovation.

Conclusions

The extent that traditional advisory organisations are supporting uptake of SFTs varies between countries. New entrants to the advisory landscape are taking a more prominent role. In the UK private companies (in the form of machinery and input suppliers) are favoured by farmers looking to implement SFTs. In Czech Republic, it is typically private companies that introduce farmers to these innovations. In France, traditional advisors and cooperatives play a more prominent role at the awareness stage, but are ill equipped to provide ongoing support. Likewise, in Norway, all types of advisors play a role in assesing the potential of SFTs, but some actors are more critical during the implementation stage because they have become specialised in specific technologies. In Norway, milk cooperatives have become skilled in technology, so it is not only the technology providers who are able to provide all of the necessary advice on adoption and implementation, as is the case in some other countries. The Portuguese case proves that there is a role for traditional advisors, but only if they can foster effective collaboration with hi-tech companies in implementation and ongoing support to farmers.

The extent that different actors play a role depends upon the existing advisory landscape in the region, existing relationships, trust between farmers and advisors, and the ongoing skills development of the actors and their capacity to stay abreast of technological developments. For traditional advisory services to find a place in this rapidly developing landscape, it will be increasingly important to recruit technologically skilled employees, and work with them to provide appropriate advice and support at all key stages of SFT adoption. Technology expertise is necessary, as is the understanding of how these technologies work in different agronomic situations. A combination of skills is therefore required if traditional advisory organisations are to strenghten their role in helping farmers in assessing whether specific SFTs are appropriate for individual farms.

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ADVISORY SUPPORT ON NON-TECHNOLOGICAL INNOVATIONS ON FARMS: THE CASE OF DIRECT MARKETING

Livia Madureira[a]; Carla S. Marques[a]; Ana Barros[b]; Cristina Micheloni[c]; Davide Zimolo[c]; Anda Adamsone-Fiskovica[d], Irina Toma[e], Ana Barandiaran del Olmo[f]

[a] UTAD & CETRAD Unit Research, Portugal
[b] UTAD, Portugal
[c] Vinidea (Italy)
[d] Baltic Studies Centre (Latvia)
[e] Highclaire Consulting (Romania)
[f] INTIA (Spain)

ABSTRACT

Context: The search for sustainability of EU farmers, especially from the economic point of view and particularly in the case of small and medium size farms, has led to several attempts of introducing organisational and marketing innovations, not linked to new products of new technology. Often these innovations are implemented through collective approaches – a factor that along with its positive effects also brings various challenges and requires specific skills.

Purpose: The paper addresses the question of if and how are the Farm Advisory Systems (FAS) supporting farmers in the implementation of non-technological innovations in various countries and in different social environments. It also aims to understand what skills and knowledge are required for a successful implementation of organisational and marketing innovations and who can provide this knowledge and skills to farmers.

Methodology and approach: The research is based on five case studies carried out in the H2020 AgriLink project. These cases pertain to the use of direct marketing by farmers, in collective or individual form, in Italy, Portugal, Latvia, Spain, and Romania.

Results and Implications: The paper advances our understanding of the present and prospective role of agricultural advisory services in the domain of non-technological innovations. The obtained results also address the needs of FAS in terms of training and innovative work modality in order to be supportive to farm-level innovation adoption. Furthermore, the role of new actors in the AKIS (Agriculture Knowledge and Innovation Systems) are discussed and recommendations for policy-makers and rural development agents are provided.

INTRODUCTION

Innovation is seen as one of the main drivers of productivity, profitability and competitiveness in the agricultural sector (OECD, 2013). Despite this, there is evidence that the European agricultural sector is not reaching its full potential in terms of innovation and there are considerable differences in agricultural innovation across countries (e.g., OECD, 2013). This can partly be explained by the fact that policies, institutional settings, infrastructural environments and/or knowledge transfer systems differ between countries. While agricultural innovative performance differs across countries, it is also the case that innovative activity is generally not uniformly distributed across regions: there may be regional dynamics at play that also affect innovation efforts (Läpple, Renwick, Cullinan, and Thorne, 2016). In these innovation regional dynamics agricultural advisory services are expected to play a key role.

The interest in assessing the role and effectiveness of agricultural advisory services is not new, but has been much more common in developing countries, where supporters wanted evidence that their investment was worthwhile (Swanson and Rajalahti, 2010). Evaluations of advisory services in developed countries and in Europe are rare (OECD, 2015), and tend to focus on the farm level and specific advisory methods. Agricultural advisory services are meant to provide farmers with relevant knowledge and networks for innovation, as well as adjustments to policy and markets in agriculture. Despite substantial investment into these services, there has been little evaluation of their performance and impact, in particular at a system level (Prager, Creaney, and Lorenzo-Arribas, 2017), on the performance of small and medium size farms and with respect to non-technological innovations (incl. marketing and organisational ones).

This paper contributes to fill this gap taking into account that search for sustainability of EU farmers, especially from the economic point of view and particularly in the case of small and medium size farms, has led to several attempts of introducing organisational and marketing innovations. Often these innovations are implemented through collective approaches – a factor that along with its positive effects also brings various challenges and requires specific skills.

The paper addresses the question of if and how are the Farm Advisory Systems (FAS) supporting farmers in the implementation of non-technological innovations in various countries and in different social environments. It also aims to understand what skills and knowledge are required for a successful implementation of organisational and marketing innovations and who can provide this knowledge and skills to farmers. The paper poses the following research questions: 1) who is acting as a farm adviser regarding non-technological innovations such as direct marketing?; 2) what are knowledge and skills demanded by farmers with respect to direct marketing; and, 3) how can different knowledge domains be integrated and become useful to the farming community?

The research is based on five case studies carried out in the H2020 AgriLink project. These cases pertain to the use of direct marketing by farmers, in collective or individual form, in Italy, Portugal, Latvia, Spain, and Romania. In all cases a set of interviews with farmers and other AKIS actors provided the empirical basis for a thorough analysis of the farmers' knowledge needs, the FAS' readiness and capacity to supply the required support, the role of different formal and informal advisory actors in farmer decision-making, and the knowledge gaps inhibiting successful implementation of direct marketing solutions by farms.

The article proceeds as follows: the next section presents a brief literature review on innovation in agriculture and on farm advisor system. Methods and empirical data underlying the study are then introduced, followed by a description and discussion of the research results. The article ends with some concluding remarks.

LITERATURE REVIEW

Innovation in agriculture

Innovations are generally divided into technological (product and process) and non-technological (organisational and marketing) innovations (OECD/Eurostat, 2005; OECD, 2010). However, these general distinctions do not recognise that most firms' innovations encompass a vast range of activities. A set of innovation activities that are implemented together are often called modes of innovation (OECD, 2010). While the dominant image of innovation is the technological one (e.g., a new product or process applied in production), there is a vast array of innovations that are less tangible but still highly important, including, for example, changes in thinking and behaviour (e.g., environmental issues), new collaboration agreements between firms and between firms and others actors, establishment of a collective brand for one common product, etc. It is often the case that the terms revolutionary or radical are used in the context of innovation, though it can equally apply to smaller more incremental changes (OECD, 2013) or mimicking (e.g., where a successful technology or approach from outside agricultural industry is transferred or applied in this industry). As some refer to innovation as a complex social process (Vanclay, Russell and Kimber, 2013), it is not surprising that there is considerable ambiguity in terms of defining innovation, which became obvious by considering the above mentioned innovation possibilities.

In this article, the authors adopt the view that innovation in agriculture is a broader set of complementary strategies (OECD, 2010) and measure innovation by three components (Läpple, Renwick and Thorne, 2015): (i) innovation adoption, which are modes of innovation relating to farm performance improvement, (ii) acquisition of knowledge, taking into account the importance of knowledge development for innovation (Spielman and Birner, 2008), and (iii) continuous innovation, underlining the need for ongoing innovation (OECD, 2013). The idea behind this innovation index is an attempt to capture and reflect the complexity of agricultural innovation.

Agricultural innovation is a process that involves the input of several actors (e.g., Klerkx, van Mierlo and Leeuwis 2012; Lamprinopoulou, Renwick, Klerkx, Hermans and Roep, 2014). That is, agricultural innovation evolves as a result of interactions among different individuals or systems. An innovation system is 'a network of organisations, enterprises, and individuals focused on bringing new products, new processes and new forms of organisations into social and economic use, together with the institutions and policies that affect their behaviour and performance' (World Bank, 2006, p. xiv). The innovation systems approach means moving away from the idea of the development and diffusion of technologies being a linear process involving public sector research and extension organisations (i.e., innovation simply being a product of science), to one with a wider focus on all of the organisations responsible for innovation. In this paper we focus our attention on the role of advisors and farmers in the agricultural innovation system at the farmers' micro-scale related to direct marketing.

It should be noted that the extent to which farmers adopt available innovations and the speed by which they do so determines the impact of innovations in terms of productivity growth. It is a common phenomenon that farmers, like any other kind of entrepreneurs, do not adopt innovations simultaneously as they appear on the market. Diffusion typically takes several years and mostly follows some sort of an S-shaped curve in time: some farmers choose to be innovators (first users) while others prefer to be early adopters, late adopters, or non-adopters (Diederen, van Meijl, Wolters and Bijak, 2003).

Farm Advisory Systems

Farm advisory services are only one component within the larger Agricultural Knowledge and Innovation System (AKIS). The AKIS concept describes the exchange of knowledge and supporting services between diverse actors from the first, second or third sector in rural areas (Prager et al., 2017).

The AKIS concept offers a multi-actor perspective designed to deal with the complexity and the diversity of information sources and channels in rural areas. The conception of an AKIS includes research and education, training, and advisory services (World Bank, 2012), with the innovation system literature broadening this conception to emphasise the role of public funding and policy, market developments, as well as systemic intermediaries in innovation support (Klerkx and Leeuwis, 2009). Although the AKIS concept is increasingly recognised as a relevant concept at the European level (EU SCAR, 2013), its use by policy makers has remained limited until recently.

Agricultural advisory services can be conceptualised as an intangible service activity (Gadrey, 2000), where the entity transformed by the services are the skills, knowledge and attitudes of the people involved in farming activities. The services can be provided by independent advisors and consultants, by organisations employing advisors such as government agencies, farmer-based organisations (FBOs) or non-governmental organisations (NGOs). The farmer-advisor relationship is embedded in the wider institutional context and regional/national policy objectives (Labarthe and Laurent, 2013). Here, we adapt the definition of micro-AKIS (Agricultural Knowledge and Innovation Systems at the farmer micro scale) used in AgriLink that describes the micro scale knowledge-system that farmers personally assemble, including the range of individuals and organisations from whom they seek service and with whom they exchange knowledge, the processes involved, and how they translate this into innovative activities (or not). The empirical uptake of this concept entails answering two questions: a) who influences farmers (and farm households) in decision-making on adopting or choosing to not adopt innovations; and, b) how does it take place, in other words, what are the processes describing the knowledge assemblage by the farmers and role played by the different sources involved.

AgriLink defines the Regional Farm Advisory Systems (R-FAS) as the set of organisations that enable farmers to develop farm-level solutions, enhance skills and coproduce knowledge with advisors. These are viewed by AgriLink from a pluralistic point of view, including traditional advice providers (chambers of agriculture, public bodies, etc.), farmer-based organisations (unions, associations, cooperatives, etc.), independent consultants, NGOs, upstream or downstream industries, and high-tech sectors. Hence, R-FAS covers the full range of these organisations in a given region, and their connection to wider AKIS organisations, and as well as a range of services, including research, advice and brokering, meaning they can be active at different steps of the farmers' decision-making processes, and use different methods at these different steps.

METODOLOGY

The research is based on five case studies carried out in the H2020 AgriLink project, looking at the role of advisory support in adopting direct marketing as a non-technological innovation. These cases pertain to the use of direct marketing by farmers, in collective or individual form, in selected regions in Italy, Portugal, Latvia, Spain, and Romania.

The methodological framework implemented in this research consisted of a mixed-method strategy: combining a case study approach with quantitative survey-type data collection. It was implemented in two major steps: 1) the case studies selection (five case studies in five European countries); 2) the survey of farmers and of advisory service suppliers.

The farmers' survey was conducted through a questionnaire comprising both open-ended and closed-ended questions intended to gather quantitative data on 'who' and 'how' types of questions (who are the advisory service providers and how these services are provided), along with qualitative data on the why and how type of questions allowing for in-depth understanding of farmers' micro-AKIS. Quantitative data from farmers' survey were entered into a joint database, while qualitative information and narratives descriptions were recorded and analysed by individual researchers.

The advisory organisations' questionnaire built mainly on closed-ended questions and addressed formal providers of advice, excluding informal providers. Formal advisory service suppliers are organisations providing advisory services as a primary activity, eventually combined with the supply of inputs or software. In-depth information on the R-FAS was gathered through interviews with key AKIS actors within the innovation uptake context.

The farmers' survey was implemented through face-to-face interviews, conducted between June and December 2018, while the advisory supplier survey was self-administrated or conducted by phone. The interviewed farmers were selected to purposefully cover innovation adopters, (informed) non-adopters, and droppers (farmers that abandoned the innovation). The innovation at stake was direct marketing of farm products done by the farmers themselves, individually or collectively organised. Hence the target farmers in all the involved countries were the small and medium scale family farmers that envisaged (or not) the adoption the direct marketing as a way to improve the economic sustainability of their farms. A snowball-type sampling procedure was adopted relying on the support of key-informants ('gatekeepers'). The surveyed advisory service suppliers were selected using a similar procedure, building on the farmers' identification of their advice suppliers in the given domain of activity.

The surveys allowed for the gathering of both qualitative and quantitative data from farmers and quantitative data from advisory suppliers. While using the full reports on the individual cases produced by the national teams based on the while set of data, this paper primarily focuses on the qualitative insights into the farmers' micro-AKIS to answer the research questions.

RESULTS

Table 1 shows the number of farmers and advisors that responded to the survey and identifies interviewed farmers with respect to their relationship with the innovation: adopters, non-adopters, and droppers.

Table 1. *Interviewed farmers and advisors by case study and classification of farmers according to their situation with respect to the innovation of direct marketing*

Country	Farmers			Total	Advisors
	Adopter	Non-adopter	Dropper		
Italy	24	4	4	35	3
Latvia	21	6	3	38	8
Portugal	14	9	14	40	3
Romania	18	16	3	43	6
Spain	18	18	2	44	6
Total	**95**	**53**	**26**		**26**

Table 2 provides an overview of the findings across the five case studies with respect to the innovation features, the adopters' characteristics, the advisory suppliers involved in the support of the innovation and the type of knowledge and skills demanded by farmers to implement the innovation. The cross-comparison of the five case studies evidences a number of common and contrasting patterns with respect to farmers' micro-AKIS. It evidences a small but still present role of conventional advisory service providers in some of the case studies, and the emergence of new advisory service suppliers to fill advisory gaps, which are prevalent in the case of this type of non-technological innovation.

Different approaches to direct marketing

The cross-comparison evidenced two groups of cases studies. One of them, comprising the case studies from Italy and Portugal, have focused on a particular type of direct marketing, collectively organised producers (groups of farmers) selling their produce to established groups of consumers. Hence, these cases entail both marketing and organisational (collaborative) innovation. The other three case studies, from Latvia, Romania and Spain, didn´t target a particular type of direct marketing and focused instead on a variety of schemes of direct marketing from retro-innovation to novel ones, like online sales. The three cases encompass mostly individually led direct marketing solutions.

4.1.1 Collective direct marketing approaches:

The case studies from Italy and Portugal offer insights on how collective action can be successful in direct marketing innovation. This is particularly important when the farmers involved are small-sized and need to collaborate to be able to develop successful short supply chains. The two case studies bring in contrasting insights in this respect.

The region of Friuli Venezia Giulia (Italy) features a successful collaborative innovation as shown by the reduced number of (informed) non-adopters and droppers (see Table 1), whereas the region of Tâmega e Sousa (Portugal) evidences a collaborative innovation failure considering the number of non-adopters, but specially the substantial number of droppers (that are in the sample in line with the study population). What are the explanations for such a divergent path of the innovation?

The Italian case was launched by a volunteer action of a pioneering group of farmers and consumers. It configures a bottom-up initiative without any support both from funding policies or regional advisory services. The motivation to the creation of the collaborative groups involving both producers and consumers was not focused on the commercial success but instead on the formalisation of already pre-existing informal cooperation between organic farmers and consumers.

This informal cooperation, built on shared values and practices of collective action, created room for the development of an NGO that brought together farmers and small scale processors and enabled consumers to get a diversified set of farm products, including vegetables, fruits, fresh and processed meat, processed products, such as jams, olives and olive oil, among other. The NGO acted as an organiser and a facilitator assembling the products and preparing the packages pre-ordered by consumers. The success of the initiative allowed for hiring two independent freelancer advisors that support the producers regarding the legal and the logistical aspects. The knowledge and skills accumulated by the pioneering farmers and consumers through attending workshops, visiting other initiatives, testing and experimenting are currently potentiated by professional advisory service providers. The innovation development created its own AKIS, and the farmers' micro-AKIS reduce to the NGO support and to informal peer-to-peer advisory. The main advisory challenge in this case is how to couple its successful direct marketing scheme that attracts a growing number of producers and consumers, with the foundational values of the pioneers, comprising no-profit related values, such as mutual trust and collective well-being.

The collaborative scheme for direct marketing in Tâmega e Sousa (Portugal) was launched by a project led by a LAG from another Portuguese region. The project started with a pilot initiative encompassing a local LAG, and later expanded to the entire region by the action of a second LAG. The project was awarded a status of European Good Practice and has attracted the Portuguese media attention. Hence the LAGs were able to mobilise other actors, such as local governments and local cooperatives to support them in the awareness stage. The scheme attracted initially both small-scale family farmers and more specialised medium-sized young farmers. This happened because the innovation assessment stage was basically reduced to the observation of successful innovation on other farms outside of the region. The actual assessment only took place after the implementation stage. The implementation of the innovation rapidly pulled out the more specialised farmers that moved to other direct marketing schemes (e.g. delivering to restaurants or gourmet retail stores) or re-oriented to bulk selling to cooperatives, similar to non-adopters. The farmers' groups were made up of 4 to 6 producers that weekly organised boxes with a diversity of fresh vegetables and fruits pre-ordered by the consumers. The groups have to organise the delivery logistics and to share the transportation costs.

With the ending of the funding for the LAG these organisations only were able to support farmers with general counselling and by providing them consumers' contacts. The self-sustainability of the initiative was part of the project design, and the LAG were supposed to step out after setting up the farmers groups. However, without the direct support of the LAGs farmers weren´t able to maintain the groups. Several difficulties accumulated along the process. The fact that all the producers produced basically the same products making difficult to diversify the offer to consumers, the transportation costs and the delivery logistics, the effort of meeting consumer demands, along with the fiscal complications (taxation is on products and not on the boxes), reduced the profitability of direct selling and the groups broke up. Some of the farmers continued doing direct marketing, but with an individually led strategy even if formally established as a farmers' group, by joining another farmer they trust, often different ones in different groups. Hence, the currently "adopters" work differently, and the initial collaborative (organisational) dimension of the innovation is largely lost.

In this case study an AKIS was also created, led by the LAGs and involving other actors, such as the local governments, the local cooperatives and NGOs, but it fell apart with the project ending. The farmers' micro-AKIS was also reduced in number and diversity of actors, with the LAGs playing a central role along with the informal ties the farmers had with cooperative advisors. Peer-to-peer advisory support was also important and basically was the only form of advisory support that continued when the individually led strategies replaced the collaborative ones. Specialised advisory support is also mobilised related to bookkeeping and ICT solutions related with issuing electronic invoices.

4.1.2 Individually-led direct marketing approaches: from retro-innovation to novel schemes

The cases from Latvia, Romania and Spain bring in insights into individually led direct marketing strategies. These are largely potentiated in the case of Latvia and Romania, due to the geographic location of the selected regions, Pierīga and Giurgiu, in the surroundings of major metropolitan areas, Riga and Bucharest.

The Pieriga case study (Latvia) highlights the revitalisation and recreation of traditional direct marketing, a retro-innovation, with the involved farmers relying pretty much on their family and social networks to directly deliver their products to permanent clients going to their residential areas or places of work. Other channels used are local and farmers' markets, on-farm sales, farm shops. On-line sales are starting to emerge. For many farmers, the knowledge and skills necessary for direct marketing are part of their experience and family history. In other words, direct marketing is part of their everyday routine. Farmers perceive this knowledge about direct marketing as experience-based knowledge. Thus advisors and advisory organisations in the narrow sense had played a peripheral role in this process. The main sources of information and learning mentioned in the interviews were personal observations made at markets, exchanges with other farmers, feedback from clients and professional literature, as well as adcice provided by organisers of specific markets. Attendance of courses was also mentioned, but these events were seldom specifically about direct marketing, though they did involve bookkeeping and rural tourism, which have a connection with direct marketing. Sales and communication skills, economic skills, the ability to respond to consumer demand and planning, as well as practical skills to do with marketing, packaging, driving and having the necessary documentation, as well as language proficiency (Latvian, Russian, English) were considered important for successful implementation of direct marketing. Farmers involved in direct marketing are not organised in cooperatives or producer groups where targeted knowledge sharing or learning would take place.

Aside from the benefits, social learning and informal peer-to-peer learning has the undesirable side effect of narrowing down the range of channels and forms for selling one's products if no one in the particular social circle has experience with novel forms and channels. Access to knowledge possessed by other groups is, therefore, very important and could be facilitated by institutional learning.

The Giurgiu case study (Romania), while comprising also a retro-innovation trend, evidences a strong emergence of more sophisticated direct marketing patterns, encompassing organisational innovation, and great involvement of the buyers, gourmet retailers and restaurants responding to growing niche market demands from a variety of sophisticated consumers, including gourmet, vegans, etc. The novel direct marketing strategies in this case encompass on-line delivery services and supermarket-led cooperatives involving networks of small-scale farmers.

Advisory support to direct marketing in the Pieriga and the Giurgiu case studies relies mostly on peer-to-peer informal networks, involving neighbours, relatives and consumers and organisers of local and farmers' markets. Buyers, such as the retailers in the Romanian case, are an important emergent advisory service supplier helping farmers to address market and consumer demands. In both cases specialised advice on fiscal and bookkeeping is provided by farmers or by NGOs. In Romania, local public advisory services appear to play a role, although residual, in supporting farmers with legal and food safety issues and by promoting the awareness on the innovation.

Advisory landscape in organisational and marketing innovation

The common pattern evidenced by the five cases, in spite of different strategies of direct marketing involved is the absence of a farm advisory system able to respond to the farmers' advice needs. The innovation emerges and develops aside the respective R-FAS, the role of which varies from none to residual support to this type of innovation. Additional shared features by all the case studies are: 1) the growing importance of clients and market actors, new players in advisory landscape with respect to this innovation; 2) the key role of informal peer-to-peer advisory support; 3) the diversity of knowledge and skills needed and demanded by farmers involved with direct marketing, and 4) the absence of specialised advisory services to respond to them.

4.2.1 Growing role for new players in advisory support: clients and buyers

The role of clients and buyers as informal advice suppliers in direct marketing innovations is not surprising. It derives from the nature of the innovation that aims at bringing closer primary producers and consumers. The insights from the case studies suggest that the greater their involvement the more successful the innovation. The Italian case of collective-led direct marketing shows the importance of joining in farmers and consumers sharing similar values to the success of the initiative. By contrast, the Portuguese case where the buyers (consumers) had a more passive role appear to have contributed to the failure of the initiative.

The Romanian case also highlights the role of buyers and clients as players in advice provision supporting farmers with the development of sales channels, product selection and production-orientation, introducing new crops, converting to organic farming, etc., packaging and logistics decisions.

However, the role of these market-led players tends to be informal, with the exception of the Italian case, where they were also founders of the NGOs that led the innovation development. Hence the involvement of consumers and buyers as co-producers of the innovation appears to be a critical factor for the success and sustainability of the direct marketing approaches.

4.2.2 Peer-to-peer informal advisory networks and tradition in direct sales

In all the case studies, with the exception of the Navarra case study where direct marketing is an emergent innovation not relying on tradition, traditional direct marketing approaches were present with larger or smaller extent. Individually led direct marketing strategies in the cases of Latvia and Romania evidence an evolution from intense tradition of direct selling in the respective regions. The innovation configures a more incremental evolution in the Latvia case, and more radical change in the Romanian case study. Nevertheless, both cases highlight the importance of peer-to-peer informal advisory support involving family and social networks.

The Italian and Portuguese cases highlight a different trend that is the creation of disruptive forms of approaching farmers and consumers that weren´t traditionally connected. In fact, some of the innovation droppers in the Portuguese case recovered their traditional direct marketing channels, like local markets and on-farm sales, the limited profitability of which have led them to adopt the innovation. In both cases peer-to-peer advice appears as an important source of advisory support across all stages of innovation adoption, and in particular during implementation. The main difference is that the Italian peer-to-peer advisory network comprised the pioneering producers and consumers that had accumulated knowledge and experience to share with newcomers, whereas in the Portuguese case there wasn´t a role for pioneers, and adopters had to learn from and with each other. In both cases, maybe with more evidence in the Portuguese case, due to shortage of advisory services, farmers relied on their informal relationships to obtain more specialised support on topics like ICT use related to fiscal matters.

4.2.3 Organisational and marketing innovation demand for holistic multi-topic advisory

Table 2 underlines that in all case studies farmers need advisory support on many topics that should be offered in a holistic manner. In addition to the agronomic advisory support, which is particularly important for new entrants, such as young farmers or rural entrepreneurs, there is a need for advisory support in a series of non-conventional topics in farm advice, such as information on legal and fiscal requirements, food safety and packaging, knowledge on logistics and marketing, along with digital, communication and soft skills related with interaction with the consumers. This diversity of advisory topics it's currently provided only separately and at a prohibitive cost. Hence, in all cases, farmers rely on their informal networks and assemble themselves pieces of this knowledge and skills that results in multiple gaps in their micro-AKIS.

Table 2. Overview of findings in the five direct marketing (DMAR) case studies

Case study	Description of innovation	Adopter profile	Advisory support supplier	Knowledge and skills demanded by farmers
DMAR in Friuli Venezia Giulia (Italy)	Initiative of a group of pioneering farmers and consumers that together with an NGO created a DMAR group; The group is growing with the entrance of farmers and consumers attracted by the success of the initiative	Small and medium organic farmers and processors, producing a variety of products	No role for conventional advisory services; Advisory support supplied by an NGO focused on local advisory supply to organic farming (NGO hires freelance independent advisors)	Multidisciplinary: Agronomic, Legal, Logistics, ICT tools, Communication (soft skills to interact with consumers)
DMAR in Pierīga (Latvia) (a peri-urban area nearby the capital city Riga	A variety of direct marketing forms was observed: Local and farmers' markets, on-farm sales, farm shops, permanent clients, sales in market towns, delivery to residential areas and places of work, and online sales.	Small and medium farmers and processors, producing a variety of products; Includes both young and experienced farmers	Informal advice is predominant, building on peer-to-peer networks involving neighbours, relatives, fellow practitioners and organisers of specific markets.	Multidisciplinary: Agronomic, Legal, Fiscal, Communication (soft skills to interact with consumers), Business planning and marketing, Languages
DMAR in Tâmega e Sousa (Portugal), a countryside area (relatively close to Porto conurbation)	Groups of farmers (4-6) join to deliver weekly pre-ordered boxes of fresh vegetables and fruits directly to consumers in pre-established pick-up spots	Small-scale family farmers, with polyculture farming systems; More females and more educated than non-adopters	Residual role for conventional advisory services; Advisory support supplied by Local Development Action Groups (LAG) associated to a project frame that ended with the implementation of the innovation	Multidisciplinary: Agronomic, Legal, Logistics, ICT tools, Communication (soft skills to interact with consumers)

Table 2. Overview of findings in the five direct marketing (DMAR) case studies (Continuation)

Case study	Description of innovation	Adopter profile	Advisory support supplier	Knowledge and skills demanded by farmers
DMAR in Giurgiu (Romania) is a consumption countryside area nearby Bucharest (The major conurbation of Romania)	Variety of novel direct marketing approaches, including farm shops, on-line delivery services, supermarket-led cooperatives involving networks of small-scale farmers	Small-scale family farmers, farming systems varying from polyculture to more specialised in niche gourmet crops; More educated than non-adopters.	Some role for conventional advisory services, in particular to public advisory services at the awareness stage; Important role for new advisory suppliers, the business partners of the farmers (ranging from clients, traders to business partners and farm contractors); informal peer-to-peer advice is a key system to exchange knowledge related to the innovation.	Multidisciplinary: Agronomic, Legal, Logistics, ICT tools, Communication (soft skills to interact with consumers), business planning and marketing.
DMAR in Navarra (Spain)	Direct marketing forms are emergent, with the exception of direct selling of DOP cheese. Fresh vegetables and beef producers are starting to adopt direct selling (local markets, direct deliveries to consumers or to restaurants)	Small to medium specialised farmers	There is a role for conventional advisory services, Navarra applied research and extension institute launched a line to support direct marketing, although currently only offers advisory support on a limited number of issues beyond conventional agronomic knowledge, such as food safety regulation and business planning and marketing in partnership with local cooperatives	Multidisciplinary: Agronomic, Legal, Logistics, business planning and marketing.

CONCLUDING REMARKS

What can be learned from the insights brought in by these different five case studies across Europe regarding how advisory services can be organised to encompass advice provision on non-technological innovation, such as direct marketing?

Firstly, only a holistic advisory system could provide an integrated supply of the multi-topical, mostly outside the agricultural domain, set of knowledge and skills needed by marketing and organisational innovations involved by direct marketing approaches. Individually-led approaches can benefit from already exiting organisations, namely NGOs, specialised offices of local governments, R&D sector related incubators, focused on supporting business planning, marketing, fiscal and digital competences of micro-entrepreneurs. However, this needs to be articulated with advisory support on agronomic and other production aspects that could be provided by the conventional advisory system when available, such as FBOs, local public advisory systems (still present in Latvia and in Romania, for instance) or independent farm advisors. An obstacle to the integration of different advisory organisations from different sectors in the support provision is the lack of tradition in this type of cooperation along with its costs. In addition, specialised knowledge related to the legal aspects of food safety, as well as to logistics and design (e.g. for packaging and branding), along with a set of soft skills related to communication, customer service, conflict resolution etc. is also needed to implement sustainable direct marketing schemes, both collectively or individually-led. The formal involvement of consumers or buyers in the development of direct marketing schemes as shown by the Italian and the Romanian cases is a good advisory practice, in particular if the schemes have the scale to recruit external advisors.

However, to make direct marketing a feasible alternative for small to medium-sized farmers, with different models for polyculture and specialised farmers, regional AKIS need to be created. The case studies show a diversity of fragmented solutions that might work better if used in a complementary manner. Devoted organisations, such as the NGO created in the case of Friuli Venezia Giullia (Italy) seem to be indispensable to act as facilitators enabling the coordination of the available cross-sector advisory support providers on the regional level and enhancing a strong involvement of consumers and buyers in the development of the innovation.

This study contributed to a deeper understanding of what kind of support is demanded for direct marketing.

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ENABLING ENVIRONMENTAL INNOVATIONS ON FARMS: WHAT IS THE ROLE OF FARM ADVISORY SERVICES?

Sandra Šūmane[a], Emīls Ķīlis[a], Daan Verstand[b], Ellen Bulten[b], Noelia Telletxea Senosiain[c], Lívia Madureira[d], Helen Zarokosta[e]

[α] Baltic Studies Centre, Latvia
[b] Stichting Wageningen Research, The Netherlands
[c] Institute for Agrifood Technology and Infrastructures of Navarra, Spain
[d] Universidade de Tras-os-Montes e Alto Douro (UTAD), Portugal
[e] Agricultural University of Athens, Greece

Introduction

Growing concerns over the environmental impact of food production have given rise to a range of environmental innovations[5] in agriculture (Sayer and Cassman, 2013). Among them, biological and integrated pest control (B/IPC) are seen as tools to reduce pesticide use, enhance biodiversity, improve water quality, limit adverse health impacts on human health, and mitigate climate change caused by agriculture (Geiger et al., 2010; Crowder and Jabbour, 2014; Dhananjayan and Ravichandran, 2018). Despite these benefits and policy incentives to reduce pesticide use and support environmentally friendly farming practices (Lee et al., 2019; Lefebvre et al., 2014), farmers' perceived values and adoption of B/IPC techniques remain low (Zhang et al., 2018).

There are complex personal and structural reasons behind farmers' reluctance to adopt environmental innovations, such as disapproving attitudes, characteristics of the innovation that make it too complicated or costly to introduce, low demand, poor institutional support and others (Vanclay and Lawrence, 1994; Wensing et al., 2019; Clausen and Fichter, 2019; Long et al., 2016). Farmers' knowledge and understanding of the innovation guide his/her innovation decision-making. Therefore, to encourage a more widespread use of B/IPC on farms, farmers' access to knowledge and advice about these methods is of key importance.

This paper aims to explore the role of the farm advisory system in enabling implementation of environmental innovations on farms. By farm advisory system we understand the set of actors - both formal and informal, individuals and organisations - who provide farmers with the advice necessary to operate a farm, develop farm-level solutions and enhance farmer skills and knowledge. We use the *triggering change cycle model* of innovation uptake developed as part of the EU Horizon 2020 project AgriLink, and apply it to five cases of B/IPC in five European countries to examine B/IPC advisory landscape and interplay of various sources of knowledge in farmer decision making in different contexts.

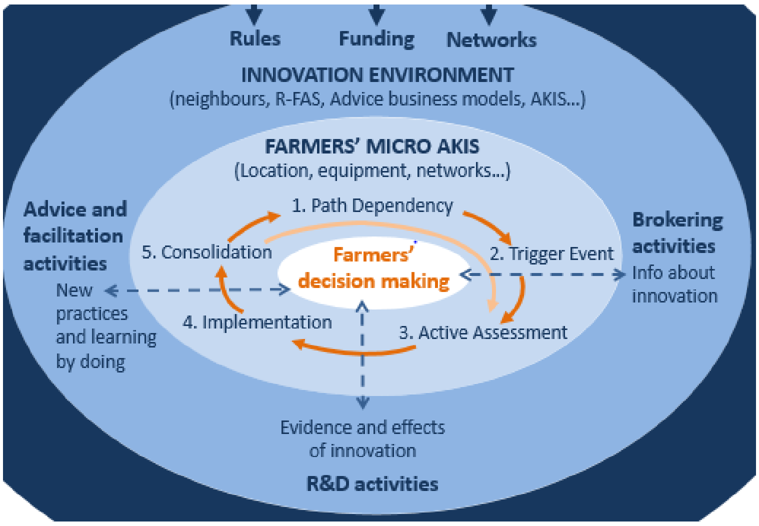
Conceptual framework: Triggering change cycle[6]

This paper approaches farmers' environmental innovation adoption behaviour from a multi-level, relational and dynamic perspective. It assumes a farmer's embeddedness in a broader innovation environment and posits that a farmers' decision to adopt and maintain an innovation depends on a set of personal and institutional settings (see Figure 1). Farmers operate within their personally assembled micro scale knowledge and innovation system

[5] By environmental innovations we understand innovation that contributes to sustainable development by reducing environmental impact, increasing resilience to environmental pressures or allowing for an efficient and responsible use of natural resources (Clausen and Fichter 2019).
[6] More information available here: https://www.agrilink2020.eu/our-work/conceptual-framework/

(*micro-AKIS)* that includes the range of individuals and organisations from whom they seek advice and exchange knowledge with (Sutherland et al., 2018). Farmer's micro-AKIS is linked to a broader innovation environment that consists of a range of agricultural knowledge and innovation institutions.

Figure 1: *Multi-level model of the cycle*



Source: AgriLink

The 'triggering change' cycle model (Sutherland et al., 2012) puts forward that farmer's decision-making regarding innovation uptake is initiated and driven by a trigger event that disrupts path-dependency and introduces new options. This breaking with the path-dependency and entering the change cycle is constituted by three phases, that can be distinguished in order to account for the advisors' role.

The first is the awareness stage that primarily refers to the farmers becoming aware of the innovation, but it also encompasses brokering activities developed by advisors to disseminate the innovation and to (co-)create trigger events influencing farmers' decision-making processes. The second is the active assessment stage, in which farmers assess the innovation. Advisors are engaged to (i) assemble information on the costs, benefits, and side-effects of an innovation, and (ii) develop and involve farmers in R&D activities. Finally, we have the implementation stage, in which advisors support farmers in their attempts to implement the innovation on their farm by delivering advice and carrying out facilitation activities. This, ultimately, lead to path dependency until a new trigger event re-initiates the cycle.

Methodology and cases

The paper is based on five case studies of farm advice in the field of B/IPC carried out as part of the ongoing Horizon 2020 project AgriLink. These case studies include the method of sexual confusion of insects in Imathia (Greece), biological plant protection methods in Vidzeme (Latvia), tagetes cultivation for nematode control in the Netherlands, biological control of grapevine pests in Douro (Portugal), and integrated pest management in Navarra (Spain) (see Box 1). Data were gathered through semi-structured interviews with farmers, advisors and experts (see Table 1) and analysed according to mixed quantitative and qualitative methods.

Box 1. Cases of the studied environmental innovations

Imathia, Greece: The case study concerns the method of mating disruption (MD) of insects implemented in the framework of the Integrated Pest Management by peach producers' groups. The method was introduced in this highly intensive cultivated area at the initiative of a local leading cooperative and a private advisory company, following export markets' demand for healthier fruits. The method includes the installation of a network of dispensers releasing pheromones across the fields. The implementation process is monitored by experts based on an annual implementation plan, therefore the establishment of collaboration relationships between the producers adopting MD and the experts is an important factor of success. Overall, the effectiveness of the method at a large scale depends on the extent of its adoption in the wider area, which is a difficult process, given the highly fragmented landscape of numerous smallholders in the area.

Vidzeme, Latvia: Given the low adoption rate of individual B/IPC techniques, the study considered various biological plant protection methods. Some notable examples among other include the targeted use of natural predators of pests (e.g. ladybirds and parasitic wasps to control greenflies) and proving special shelters for useful animals (insect houses). The underlying knowledge that farmers base upon is a mix of both traditional /local knowledge passed on from earlier generations of farmers and new research-based knowledge provided by contemporary science, which is imparted by various advisors. Vidzeme was selected due to the prominence of organic farming in this region. The assumption was that organic farmers were the most likely to use biological plant protection methods.

The Netherlands: The use of soil disinfestation pesticides is under pressure in the Netherlands, due to environmental concerns from consumers and regulations by government. These chemical products are also harmful for the environment. The pesticides are used to control nematodes which can cause damage to the crops. An alternative to chemical soil disinfection is the cultivation of Tagetus patula, which is currently used in fruit, strawberries, potatoes, roses and lily cultivation to control the nematode species Pratylenchus Penetrans. The cultivation of Tagetes is considered as an innovation, since it uses biological principles to control nematodes. Adopters of this innovation do not have to use pesticides anymore to protect their crops for the nematode species Pratylenchus Penetrans, because comparable control effectiveness levels are reached.

Douro, Portugal: The case study focused on a set of farming practices for enhancing the vineyards ecological infrastructure (EI). These comprise the vineyards green cover (seeded or spontaneous) along with the implementing and /or restoring of live hedgerows, schist walls, and maintenance of Mediterranean bushes and the remains of the oldest vines destroyed by the Phylloxera. Together these practices configure an eco-functional vineyards landscape more resilient to plagues driven by insects and other agents. The vine growers implementing the EI build on scientific knowledge and on the new empirical knowledge they acquire by testing, experimenting and monitoring the innovation outcomes. This is a time and knowledge intensive consuming innovation and their benefits on the quality of the landscape and of the grapes and the wines are only captured by medium and large vine growers which are simultaneously winemakers, and this explains why the vast majority of small and medium grape growers are non-adopters.

Navarra, Spain: This case study explored the use of Integrated Pest Management techniques in Navarra. These included the use of mating disruption, the introduction of natural enemies to control pests and the use of alternative zero-residue products in vineyards, fruit trees and horticultural crops. Some of the techniques have been used for many years but policy changes and consumer demand have led to an increase in the use of these innovations. Historically, the public advisory service has been a key actor in the dissemination of these techniques, but in recent years more and more organisations have become part of the advisory landscape, resulting in changes in knowledge flows.

The methodological framework consisted of a mixed-method strategy, combining a case study approach with survey data collection. In the selected case study regions two surveys were carried out: (1) a farmer survey on the micro-AKIS and the role of the advisory service providers during the three stages of innovation adoption (awareness, active assessment and implementation); and, (2) a survey of advisory service providers to explore farm advisory system in the region in relation with the B/IPC (see Table 1). Both surveys adopted a snowball-type sampling procedure with different information sources used and cross-checked. The farmer survey targeted both adopters and non-adopters of the innovation. The farmers were selected so that the innovation in question was relevant for their farming practices (for instance, in the Netherlands, farmers were selected on the base of their farm and soil characteristics (e.g. are their crops vulnerable for the nematodes, are the nematodes present on the specific soil type etc.), in Navarra, those farmers were targeted who cultivated crops for which the studied techniques were used in the region (fruit trees, horticultural crops and vineyards), etc.). The advisory services providers survey aimed to capture the complete spectrum of advisory organisations supplying advisory or related services on the innovation.

Table 1. *Samples of farmer and advisor surveys*

Innovation case study	Farmers				Advisors
	Adopters	Non-adopters	Droppers	Total	
Sexual confusion of insects, Imathia, Greece	25	17	0	42	10
Biological plant protection, Vidzeme, Latvia	22	15	3	40	5
Cultivation of Tagetes, the Netherlands	14	1	0	15	5
Biological control of grapevine pests, Portugal	23	17	2	42	3
Integrated pest management, Navarra, Spain	17	12	3	32	10
Total	101	62	8	171	33

Source: AgriLink

The sample represents the socio-economic diversity of farmers in the studied regions and innovations. The interviewed farms varied greatly in terms of their size: from 1 ha to 1200 ha. The farmers had various educational profiles (including those with only compulsory education, a high-school diploma, vocational training and a university degree), age, farming experience, and farm's management and commercial strategies.

The interviews were structured around both open and closed questions. Quantitative data from the surveys were entered in databases, while qualitative information and narrative descriptions were recorded and analysed in order to provide the descriptive and analytical insights. The data were analysed and synthesised according to predefined themes: farmer and farm socio-economic profile, attitude towards the innovation and change, farm's innovation path, farmer's micro-AKIS, advisory landscape in the innovation area.

Even though the cases present a variety of insights, the sample is not random and, therefore, has limitations. Our findings cannot claim to be representative of the complexities attendant to implementing B/IPC. Nonetheless, cross-comparison between the cases and interviews has identified several issues in farm advisory systems that are of common relevance to many farmers in different regions. Consequently, while not exhaustive, our findings are indicative of common issues, experiences and obstacles that affect farmers who are engaged with the environmental innovations in question.

Results

In this section we present the societal and knowledge contexts of the studied environmental innovations, the principal sources of advice on B/IPC that farmers consult and interlinks of different sources. We identify good practices in providing knowledge and advice to farmers, as well as gaps in the provision of advice.

4.1. Environmental innovations in dynamic contexts

The studied environmental innovations differ in terms of their scope of implementation and history in each of the regions. Some of the innovations have been developed and implemented recently, like mating disruption in Greece and biological control in fruit trees in Spain. In these cases, the innovations are based on recent scientific research. However, many of the environmental innovations considered in this paper - like, tagetes in the Netherlands, and some B/IPC methods in Latvia and Spain - are more akin to retro-innovations. These methods have been known in the agricultural community for several decades but have been abandoned in place of more intensive chemical methods or have been continuously practised by a minority of farmers with specific profiles, like organic, small-scale or semi-subsistence farmers. Knowledge of these 'older' methods has been maintained among a comparatively small number of farmers, and recent scientific research has provided evidence on their efficacy and helped to inform a broader farming community.

The variety of contexts that we consider in the study regions illustrates that the (re)integration of these environmental methods in farming practices has been stimulated by different developments and contextual triggers. Altogether they reflect the growing societal concerns over negative impact of farming practices on the environment that result in growing demand for environmentally friendlier agricultural products, and pro-environmental policy frameworks (see Chapter 4.5).

4.2. Advisory landscapes in the field of B/IPC

The results show that farmers engage with a wide range of information, knowledge and advice sources in the regions when implementing the studied environmental innovations. Often the same advisors are consulted during all the phases of the triggering change cycle. Moreover, in farmers' experiences, the phases often are not sequential and linear, but overlapping and iterative. (Therefore, we do not distinguish between the phases in the analysis that follows and refer to individual stages of the cycle only when distinguishing elements appear.) Still a specific advisors' role can be identified for each phase. In the awareness phase, advisors inform farmers on the innovation. During the assessment phase, advisors support farmers in their evaluation of the possibilities, requirements and consequences of implementing the method on the specific farm. During the implementation stage, the role of advisors consists of facilitating the farmer in making the best decisions to make the innovation a success.

The central sources of advice on B/IPC for farmers in the study regions were "traditional" agricultural advisors, peers, ie, other farmers, and farmers' organisations. When traditional agricultural advisory organisations with experts in the field are present, they play an important role in supporting the adoption of the studied environmental innovations. For example, among Dutch farmers it is a common practice to regularly consult agricultural advisors, who are key persons in introducing novelties to farmers and assisting them with implementation. Advisors visit the farms often, they know many farmers with similar problems, and play an important role in getting farmers acquainted with innovations. However, not all farmers systematically use the advice from an agricultural advisor in the decision-making process. In Greece, private advisory companies collaborate with local farmer-based organisations, influencing decisively farmers' decisions: *My respect and trust for the advisor [who informed me about the innovation] made me adopt the innovation,"* (farmer 34, Greece). Similarly, Spanish farmers also indicated that the public advisory service is ever present during the advisory cycle. To a lesser extent they were present in the Latvian case.

The importance of peers, i.e. other farmers, was evident in all cases, as farmers receive from them information and advice. Just over a third of the interviewed Spanish farmers became aware of the innovation from conversations with other farmers who were already applying or evaluating it. When Dutch farmers consider cultivating tagetes, they often visit neighbouring or experimental farms that have already started cultivating and promote tagetes. Exchange of experiences, learning and advising each other, joint learning among farmers continue to be very important in the implementation stage and the assessment stages of the innovation. A Greek farmer confirms: "*we discuss together and learn from our mistakes," (*farmer 38). Similarly, Latvian farmers indicated that many plant protection methods are simply "in circulation" among farmers, and farmers talk about the proper ways to implement them. For instance, when a Latvian farmer was asked when she first came across biological methods, she said: "*..Well, I've used folk methods since I was a child,"* (farmer 6, Latvia). This points also to the role of farming family background, and family members were listed among key advice providers, especially in the Latvian case.

When farmers are organised in production cooperatives, these collective organisations appear to be among the key drivers of environmental innovations and a source of knowledge and advice for their members. In Portugal, farmers - wine growers' organisation is simultaneously the key advisory organisation that holds the leading role in the region's transition path towards a more eco-functional farming landscape. (However, the traditional wine cooperatives are not so far playing any role in the diffusion of the innovation.) In Spain, the demand of the cooperative stimulated its members to use the technique of the mating disruption: the cooperative proposed to apply the technique in a big area, to guarantee the efficacy of the technique and reduce the costs. Similarly, in Greece, the first adopters of mating disruption were members of a leading cooperative's board.

In addition to these three key groups of advisors, other actors appear important in providing advice depending on the organisation of production and dissemination stage of the innovation. Research is an intrinsic part of the innovation generation and diffusion process as it provides scientific evidence to support innovation, and this was also the case in the countries covered in this paper. In the Netherlands, public funded research on alternative disinfestation methods and researchers' dissemination activities played a key role in the innovation process of tagetes. Researchers executed field trials to verify the effects on the nematode population and demonstrate it to farmers. Researchers were also deemed important by Portuguese farmers, as the innovation builds on scientific knowledge and requires on-site experimentation and active learning by the farmers. Multi-actor R&D projects funded by EU and national funds have shown key to the spread and deepening of the environmental innovation in Douro.

Input suppliers were also cited by farmers as their providers of advice. However, in Spain it was indicated that, because of the commercial motivation driving these companies, their advice is not as highly appreciated as the impartial advice provided by public organisations. Similar concerns were noted by AKIS experts in Latvia. The expertise of the input suppliers was not questioned, but there were doubts as to their impartiality.

As the innovations gain popularity among farmers, there is an increasing diversity in the advisory landscape. Over the years, more advisors - such as input suppliers, cooperatives and the agri-food industry - have been entering the innovation area of B/IPC methods in Spain. Also, in Greece, retailers, traders, input machinery companies and others supplement the picture of farm advice providers, albeit their advisory role remains marginal in comparison to the local cooperatives and the advisors collaborating with them. In Portugal, we note the presence of environmental NGOs and traders, which highlights the interest of consumers and the markets in dissemination of environmental innovations.

4.3. Advisory networks

All the studies cases point to the role of networking between various actors to support innovation adoption on farms. Joint and coordinated efforts of key actors have facilitated dissemination of innovations, while a lack of joint actions seems to be a hampering factor in other cases.

In some cases, more formal and institutional collaboration between key actors was established. In Greece, the shared interest to reduce the use of pesticides and developed collaboration between an advisory company and a leading cooperative led them to the initiation of pilot fields in the framework of a research program. The cooperatives and the collaborating advisory companies were often engaged in common advisory activities in order to support farmers to meet integrated pest management standards. Similarly, in the Netherlands, communication and collaboration between researchers, advisors and farmers has supported innovation diffusion. Advisors have cooperated closely with researchers to deliver information to farmers, and researchers have been actively involved to convince and assist farmers to implement tagetes cultivation on their farm. In Portugal, pioneering farmers cooperated and developed an effective farmer-based advisory organisation with strong local roots and simultaneously well-networked with other key AKIS actors at the meso-regional and the global scale. In Navarra, INTIA as the only public applied research and advisory centre in the region, played a central role acting as an innovation broker and facilitator for the transfer of knowledge.

In addition to these formal forms of collaboration, there are more informal ones. For example, the Latvian farmers indicated the significance of learning through informal networks that bring together people with common practical or commercial interests. Such formal organisations as the Association of Latvian Organic Agriculture and The Community of Environmental Health function as informal forums of advice as their members interact and assist one another on various technical issues, including pest control. In the Netherlands, many farmers are involved in 'study groups' – groups of farmers that regularly meet to discuss the problems they are facing and exchange solutions and new developments. Often these groups are facilitated by an advisor or researcher, and they are an important source of information and support, as experiences and best practices are shared. In addition, much like in Spain, several farmers indicated that they have formed their own informal network of farmers with mutual interests. In the Portuguese case informal collaboration is emerging between the large wine makers and their suppliers small-scale vine growers. Small-scale growers' interest in the innovation of ecological infrastructures and knowledge about it is gained in these informal interactions.

Even in cases where no formal networking has been established between the key advisory actors, their activities in innovation diffusion is complementary. For instance, in Spain the public advisory service played a fundamental role in raising awareness of the innovation, but so did the input suppliers who supported the practical implementation of innovation.

Finally, cooperation between different actors in the advisory landscape can provide benefits that go beyond innovation diffusion. For example, in Greece, cooperation between independent advisors and local cooperatives has induced actions aimed at influencing agricultural policies and practices at a broader scale. The advisors have facilitated connecting the local cooperatives and oriented their common actions for the innovation by supporting them with technical and advocacy services to influence policy makers for the inclusion of mating disruption in the public agri-environmental measures. In Portugal, the cooperation between the wine growers, through their association, and the researchers has shown determinant for the emergency and for the consolidation of the innovation.

4.4. Advisory gaps and challenges

The studied environmental innovations have been relatively successfully (re)introduced, but in most cases, there are still knowledge and advisory gaps that constrain their broader diffusion.

There is a lack of specialised experts on biological pest control, even though many organisations provide advice. In Greece AKIS actors pointed to the urgent need for qualified advisors in order to boost development in the farming sector and allow for the continuous improvement of quality systems. Overall, farmers' lack of knowledge and interest to participate in information and training activities hinders the diffusion of the innovation. In Portugal, the small-scale regional farm advisory system is dominated by cooperatives and farm associations that so far have not involved with the innovation of ecological infrastructures due to lack of direct benefits for their associates. Most of the advice providers on B/IPC that Latvian farmers consult, including certification and controlling bodies, are without a specific advisory function, as there are few experts on B/IPC at the farm advisory organisation.

A cross-cutting issue is the lack of impartial advice or the growing influence of commercially motivated advisory actors. In Spain and Latvia, the need for impartial advice on B/IPC methods was noted, as not all farmers have the necessary knowledge to competently and critically assess the biological method in question. The growing significance of input suppliers as providers of advice makes this need for impartial advice more acute. While the quality of advice is not disputed, it is reasonable to assume a certain bias towards the products in the portfolio of the company the advisor represents. The growing influence of input suppliers was noted in other countries as well, though it remains to be seen whether this will become a serious issue.

A common challenge for innovation pioneers and advisory providers is to transmit knowledge about alternative methods due to path-dependency in the agricultural community. For example, in Spain, B/IPC are generally perceived to be more complex than conventional techniques because they require greater monitoring commitments and products that are not harmful to the auxiliary fauna can be more expensive. *"When I decided to start using biological control techniques, I had to learn a lot about insects, their life cycles, etc. I spent a lot of time observing the crop and monitoring the evolution of pests and natural enemies during the implementation of the technique,"* (farmer x, Spain). Therefore, many farmers do not even consider these techniques. Nonetheless, all the advisory organisations interviewed acknowledged that the topic is increasingly important and that they are investing in this topic, for instance, by trials, developing decision support tools, etc.

Cooperation of different actors involved with the innovation might be needed to improve the transfer of knowledge about alternative methods and to enable their uptake in farms. For this purpose, in the Greek case, farmers' cooperatives joined efforts with private advisors. The private advisors based on agreements with the farmers' cooperatives carried out information seminars and individual discussions with growers, disseminating valuable information about the innovation, motivating and helping producers' first assessment by providing evidence about its effectiveness and guiding them during the implementation stage.

In the Netherlands, no specific problems were reported in advisory services in link to the tagetes method. However, it is mentioned that farmers need complex knowledge about the innovation that involves not only technical information about the practice and the feasibility in different farming systems, but also information about the economical results and ecological effects.

4.5. Multifactor decision-making in environmental innovations

Overall, we note that availability and access to advice on environmental innovations is a key, but only one factor among many that influence farmers' decision-making vis-a-vis the adoption of these innovation. Farmers consider various, sometimes conflicting aspects, when considering adoption of innovations, as it is illustrated by a Dutch farmer's reflections over adoption of Tagetes cultivation: *"Firstly, while the farmer recognises that Tagetes cultivation improves the soil after a few years, he is unsure whether or not it is worth the investment on rented land. What if the owner of the land decides to sell the land? The farmer feels like he would have wasted his money and not benefited from improved soil quality himself. Secondly, the farmer explained that it goes against his 'farmer instincts' to dedicate time, energy and money to cultivate a crop that is not harvested. Thirdly, the farmer thinks cultivating Tagetes is not a good fit on his farm. The farmer explained that because of the type of crops he grows, he would have to cultivate Tagetes instead of cultivating a profitable crop that he can harvest. He is still debating between either investing in the long-term benefits of Tagetes cultivation or investing in the short-term benefits of harvesting crops that are profitable right now."* (Verstand et al., 2019) Those diverse factors also suggest that the field of farm advisors' expertise might need to be enlarged beyond the technical aspects of innovative methods.

The characteristics of an innovation and farmer's estimations of the innovation's feasibility on his/her farm and of its economic benefit are the principle factors whether farmers decide or not to adopt it. For instance, the interviewed non-adopters in Spain explained their decision to not adopt an environmental method for economic reasons, their farm conditions (plot size, crop diversity, etc.) which are not suitable for the method, lesser effectiveness of B/IPC and no demand from their buyers (cooperative, winery or freezer) to apply the methods in their fields. Overall, it was believed that advisory service providers need to further demonstrate the viability of the techniques and to provide a better access to the necessary knowledge. In Greece, the basic differentiation between adopters and non-adopters was largely related to the perceived effectiveness and the implementation cost of the innovation: *"My neighbours do not adopt [the innovation], this increases my cost too much since I had to install too many dispensers in my field,"* (farmer 2, Greece). This sentiment was echoed in the interviews with Portuguese farmers that in addition to perceived direct benefits must entail into more costly practices and processes. In Latvia, some farmers suggested that the cost/benefit ratio of many BPC methods meant that they are more suited to small and medium-sized farms or farms specialising in niche products.

Farmers' environmental values and commitment play a decisive role in selection of farming methods. In Latvia, having a '"love of nature", familiarity with "ancestral methods" and an interest in organic farming were also considered important motivational factors, underlining the complex mix of practical skills, habitual knowledge and philosophical considerations involved in choosing to implement the innovation. In Spain, of similar importance was the willingness of farmers to reduce the use of pesticides in crop production and increase biodiversity. In Greece, the differences in the interpretation of human intervention in the natural balance influenced farmers' willingness to adopt the innovation. As a farmer said: *"MD is another human intervention that disturbs further the ecological balance,"* (farmer 41, Greece).

A support network and the presence of successful examples in the surrounding area can address and assuage concerns and uncertainties. In the Greek case, the existence of strong cooperatives has been the critical factor of the whole innovation process at all stages, providing farmers with advice and support. In Portugal, the dynamic created by the large winegrowers in supplying advice to their suppliers (small-scale farmers) might stimulate the adoption of environmental innovations among the more dynamic advisory organisations. The interviews in Latvia suggest that familiarity with successful examples of implementation and familiarity with the innovation as such are also important factors for stimulating the uptake of innovations that can contribute to the sustainability of agricultural practices.

As stated above, growing societal environmental awareness and demand for environmentally friendly farming practices and healthy food in general is a considerable driving force for farmers and other food system actors to consider environmental innovations. In the Greek case, a cluster of cooperatives adopted the method of mating disruption of insects to demonstrate their environmentally friendly profile in response to the growing demand for safe and healthy products. Similarly, in Spain, the growing demand of zero residue products that are more respectful of the environment stimulate farmers' interest about innovative environmental techniques in fruit and horticultural production. In the Netherlands, in some occasions health issues have supported considering alternatives to the conventional practice as people got ill as a result of being exposed to the pesticide for soil disinfestation. Also the Portuguese case illustrates the indirect impact of societal expectations as the transition to a more eco-functional farming approach was stimulated by farmers' growing awareness of future market trends, societal demands and funding opportunities.

Taking policy measures ~~a~~nd structuring a legal framework play a crucial role in turning societal concerns into concrete action. The societal demand for the environment and health protection has a considerable effect on the diffusion of environmental innovations when it is enforced by legislation. In the Netherlands, growing societal concern over agricultural has resulted in stricter regulations of chemical disinfestation. These, in turn, have been the key triggering factor for farmers and advisors to consider more environmentally sustainable alternatives. Together with the resulting increased costs of chemical disinfestation, the regulations have made tagetes as the only effective alternative in controlling the specific nematode species. Similarly, in Spain, the Directive on the Sustainable Use of Pesticides has encouraged the use of mating disruption methods, which started in the early 2000s in vineyards and has recently expanded to fruit production due to its high efficacy. Agri-environmental measures in public agricultural policies and related economic incentives of public subsidies have considerably reinforced also Greek farmers' motivation to adopt integrated pest management. The inclusion of mating disruption in the agri-environmental measures and the availability of subsidies are strong incentives for adoption alleviating some of the fear associated with the implementation of this method. In Latvia, many farmers made the switch to organic farming in view of the generous subsidies. In addition, the restrictions placed on the use of chemical pesticides may yet encourage farmers to make the switch to biological pest control methods. The role of the EU and national policies are critical to enhance advisory services on environmental innovations, as they require that the implementation of an agri-environmental measure ensures the provision of advice.

Discussion

The role of advisory services in facilitating environmental innovations in farms has to be regarded in a broader context of innovation environment. The history and scope of implementation of each innovation in the region matters as there is more knowledge accumulated and validated in practice about 'older' innovations with a certain adoption rate. This increases farmers' familiarity with successful examples of implementation that is encouraging for their own decision-making on innovation adoption. Advisors can play a key role in collecting and delivering knowledge on innovations in the regional contexts, as they accumulate their clients' on-farm experiences (Lowe et al., 2019). However, familiarity with the effectiveness of environmental innovations and appropriate conditions for their implementation on farms does not lead straightforward to their wide adoption.

It was apparent that some characteristics of the farm and/or farmer determined farmers' perception of the innovation in question and its applicability on their farm. Appropriate agro-environmental, ownership and infrastructural conditions of a farm are important factors for stimulating the uptake of innovations. Farm advisors can assist farmers with estimations and best-fit farm solutions. Farmers' personal values, attitudes and outlooks play a substantial role in the adoption process. In line with previous studies, farmers' intrinsic environmental awareness motivates them to gather information about environmental innovations and adopt pro-environmental behaviour (Wensing et al., 2019; Bopp et al., 2019). Raising environmental awareness and attitude change is a long-term process, where informing, training, educating and demonstrating - key functions of farm advisory services - are crucial elements (Despotovič et al., 2019).

In the studied cases the (re)integration of the environmental methods in farming practices were often stimulated by contextual triggers. These triggers reveal societal concerns over negative impact of agricultural activities on the environment and the growing consumer demand for environmentally friendly products. However, as environmental innovations can bring about limited commercial benefits (Cullen et al., 2013; Forbes et al., 2013), policy incentives, like restrictions of the use of chemical inputs and the availability of subsidies for environmentally friendly practices, are confirmed to be important driving forces. These point to the potential functions of farm advisors of channelling up-to-date societal demand and policies to farmers.

Previous research points to the positive impact of encouraging knowledge environment and advisors on farmers' innovation perceptions and behaviours (Sneddon et al., 2011). In the studied cases, farmers' professional social networks, including other peers in their neighbourhood and in farmer organisations (associations, cooperatives, farmer groups), and professional agricultural advisors, appeared to be key social reference groups that encourage to consider innovation adoption. These three groups - traditional agricultural advisors, other farmers and farmers' organisations - stand out also as the primary sources of advice during the implementation phase. While traditional advisors and formal organisations provide with professional advice originating in formal knowledge, farmers highly value the experience-based advice provided by other farmers in the practical implementation of innovations (Šūmane et al., 2018).

Altogether, in the studied cases farmers combine and rely upon a wide range of knowledge sources, as also other actors, like researchers, input suppliers, controlling bodies etc., play an important role of farm advisors, depending on the country and the innovations. Our research suggests that often the same advisors are consulted during all phases of the innovation cycle, starting from awareness, through active assessment and implementation; however, these phases often are not sequential and linear, but overlapping and iterative.

We note some gaps in the farm advisory system regarded the studied environmental innovations. Lack of advice and advisors in some cases indicates that some environmental innovations are not well addressed within the agricultural advisory system, and therefore the pace of their dissemination is hindered. The growing role of input suppliers raises the question of the impartiality of their provided advice and its impact on the innovation's path. Collaborative education programs involving input suppliers could help to address agro-environmental issues more effectively (Stuart et al., 2018).

More generally, there is a necessity for improvements in agricultural education and the formal advisory support provided to farmers implementing environmental innovations. Environmental aspects of farming might need more systematic approach in agricultural education and advice. Furthermore, in the landscape of (increasing) diversity of advisory providers, a joint challenge is to develop formal and informal cooperation fora that allow different actors to interact and transmit a unified message, to improve collective knowledge about alternative environmental methods, and increase successful implementation, including in economic terms, of environmental innovations on farms. Networking has approved to bring positive effects on diffusion and adoption of B/IPC, and further reinforcing of multi-actor and cross-border sectoral networks would help to address common challenges (Lamichhane et al., 2016). Better cooperation between farmers, researchers and advisors is needed also to co-create locally specific knowledge.

Conclusions

In this paper we have looked at the role of advisory system in enabling different environmental innovations on farms. Widespread adoption of environmental innovations depends on a combination of different factors, and the availability of advice is only one, still crucial and transversal element of the innovation process. Societal demand for environmentally sound farming practices and agricultural products, supported by pro-environmental public policy measures, creates often a triggering effect on farmers to consider adoption of environmental innovations. Positive attitudes vis-a-vis these innovations in farmers' key reference groups, including advisory service providers, have a pushing effect towards adoption. Farmers pay attention to various aspects of the innovation and its feasibility with the farm when deciding on its adoption. To address the wide scope of farmers' inquiries and knowledge needs in this process, it is important that advisors have a broader expertise themselves on innovation and adoption process that goes beyond the technical aspects or that they can bridge farmers to other experts. The importance of this bridging or brokering function of advisors is even more important given that the farmers tend to consult the same advisors during the several phases of the innovation process, and the growing number of advisors with commercial interests. Cooperation among knowledge actors, advisory providers and opinion leaders can promote environmental innovations in the farming community and provide full support to farmers in adoption process more effectively. Reinforced environmental education, advice and networking for practical implementation of environmental innovations will facilitate a wider uptake and better-informed use of the B/IPC methods, enhancing farmers' ability to distinguish valuable knowledge from information and taking better advantage of peer to peer learning opportunities. Further exploration of the relations between different farm advisors and their provided advice on environmental innovations, and the effect of these on farmers' innovation behaviours would help to improve innovation support system in agriculture.

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STRENGTHENING THE ROLE OF INNOVATION BROKERS IN LIVESTOCK ADVISORY SERVICES OF PAKISTAN

Warriach, H. M., Ayre, M., Nettle, R. and McGill, D.

University of Melbourne

ABSTRACT

Innovation brokers are an important component of agricultural advisory systems worldwide and have potential to impact household livelihoods in developing countries. Innovation brokers play a crucial role as systemic intermediaries that facilitate information flows, connect partners, articulate demands, communicate needs, facilitate linkages and other functions related to innovation processes (Klerkx and Leeuwis 2009; Van Lente, et al. 2003). In developing sectors, such as in Pakistan, linear and top-down models of change continue to be the major components of the farm advisory systems. Transforming the role of farm advisors in these systems to innovation brokers presents major challenges (Kilelu, et al. 2013). This paper aims to investigate the knowledge and skills required to transform individuals in linear-style farm advisory roles to play the role of innovation brokers within the livestock advisory services of Pakistan. The Whole Family Extension Approach (WFEA) was developed (Warriach, et al. 2018), and is considered an Agricultural Innovation Systems (AIS) intervention in the livestock extension system of Pakistan. This research project is building the capacity of the AIS by scaling up (Hermans, et al. 2013) the WFEA intervention through collaborative efforts with local extension partners. A network of 22 organisations (research, government, NGOs, private sector and international research organisations) with the common goal to improve smallholder livelihoods has been established. As part of the intervention, each organisation has designated up to four farm advisors to be part of a training program and a community of practice meeting (three days) after every six months about their roles in the farm advisory system. This includes training on various technical farming system modules and the opportunity to engage in a collaborative learning environment where individuals reflect on their own field experiences and the challenges they face. Data regarding the capacity building process from 50 farm advisors has been collected using two approaches; (1) through two reflective focus groups, July 2018 and December 2018, at the community of practice sessions and (2) during field follow-up visits for mentoring, monitoring and evaluation of the program. The results of this study conclude that regular capacity building trainings of farm advisors on the whole farming system, integrating female farm advisor, establishing trust and feedback mechanism among various actors involved in process, training on social mobilisation and communication skills of farm advisors are the key components to integrate the WFEA within the current farm advisory services in Pakistan. The framework proposed by Prager, et al. (2017) for the evaluation of farm advisory services could therefore be expanded for developing country contexts, including criteria on: capacity building of farm advisors; advisors meeting the diverse needs of farmers; support beyond technology transfer and support to streamline organisational extension programs.

INTRODUCTION

Farm advisory services play a vital role in the improvement of the dairy sector in low-income countries. The goal of advisory services is to provide research-based knowledge to rural communities to improve their farm productivity, leading to poverty reduction, rural development and more sustainable rural livelihoods (Swanson 2008; Zwane 2012). The role, function and structure of advisory services in any country depend on farmer education level, availability and use of technologies, level of commercialisation and value of the product (Swanson, 2008).

Innovation brokers are persons or organisations that catalyse innovation through bringing together actors and facilitating their interaction (Klerkx, 2012). They play a crucial role as systemic intermediaries that facilitate information flows, connect and innovate partners, articulate demands, communicate needs, facilitate linkages and other functions related to innovation processes (Van Lente, et al. 2003; Klerkx and Leeuwis 2009; Winch and Courtney 2007). In low-income countries, intermediary organisations connect different agents involved in innovation trajectories (Szogs, 2008), are important as they fulfil boundary work (Patti, et al. 2009) and play a role in bridging, bonding and linking social capital (Heemskerk and Wennink 2004). These, third-party catalysing agents are necessary to bring partners together, motivate them, provide information, and organise space for negotiations (Hartwich, et al. 2007). The type of intermediary that is becoming increasingly important is 'systemic' in a many-to-many relationship (Van Lente, et al. 2003; Howells, 2006). In other words, a role that is neither involved in the creation of knowledge nor in its use in innovation, but one that binds together the various elements of an innovation system and ensures that demands are articulated to suppliers, that partners connect, and that information flows and learning occurs (Klerkx, et al. 2009).

The strategies and methods to support innovation remain a challenge (Toillier et al. 2018). Innovation Support Services (ISS) depends on the phase of the innovation. During the initial phases, there is a need for innovative support services (e.g. network building, support for the innovator). In the latter phases, there is a need for more conventional services (e.g. training, credit) at farm, value chain and territory level. Brokering functions and new services are key to supporting actors to innovate by facilitating interactions for the co-production of knowledge, co-design of technologies, and identification of new institutional arrangements (Guy Faure et al. 2019). The required services are diverse (Albert, 2000; Leeuwis, Van den Ban, 2004) in terms of content (technical, economic, social, legal, etc.), and they can be provided by diverse methods (transfer of knowledge, co-con- struction, participatory development, etc.), as well as by a variety of providers (public, private, NGO, etc.). The role of agricultural advisory service (AAS) providers has changed. Over the past few decades, international efforts have been made to revitalize AAS through institutional reforms (decentralization, public-private partnerships, privatization, contract- ing-outsourcing, etc.) (Birner et al., 2009). New actors have emerged (NGOs, the private sector, including private firms and farmers' organizations), pro- moting and enhancing innovation processes by providing new services and new methods to deliver these services (Labarthe et al., 2013; Leeuwis, Van den Ban, 2004).

Agricultural Innovation System (AIS), is promulgated to undertake reforms in the knowledge and innovation support structures. In many low-income South Asian countries such as Bangladesh and India (Chowdhury, et al. 2014); (Rivera and Sulaiman 2009) they have taken initiatives to transform roles of the agricultural extension to support innovation as a collective process of putting knowledge into practice, and achieving multi-stakeholder social, economic and environmental goals. Despite this, AIS tends to be an academic window into agricultural development and requires operational concepts and tools if we want to make a real change (Spielman, et al. 2009) (World Bank, 2012). In these low-income countries, public-sector extension agencies and extension workers are finding it difficult to translate their roles from the classical model of agricultural extension to the AIS perspective (Rivera and Sulaiman 2009). Agricultural innovation studies have urged policy-makers and rural development professionals to adopt different innovative approaches to build social capital among farmers, pay greater attention to the needs of women and youth, and facilitate better links to markets for performing agricultural extension services (World Bank, 2012).

In Pakistan, farm advisory services are based on the linear top-down transfer of technology, in which technology was developed and validated by researchers, communicated by extension agents and transferred to the farmers (Ashraf, et al. 2018). However, this approach has been subjected to various criticisms, such as failure to account for the context and complexity of the agricultural sector (Pretty and Chambers 2003). This implies challenging top-down and hierarchical approaches as well as changing routines and practices to ensure learning between one-to-one, one-to-many, and many-to-many innovation actors (Hall, et al. 2004). Therefore, there is a need to transform this approach so that farmers play a more central or 'participatory' role in the acquisition of knowledge and change of practice (Cristóvão, et al. 2012). In these 'participatory' extension programmes, researchers and extension agents fulfil a facilitating role, while farmers actively set the agenda and engage with their peers (Black, 2000).

Improving human capacity to play the role of innovation broker is the first and foremost step in AIS. It requires skills related to process facilitation: leadership, multistakeholder facilitation, trust building, and communication; it also requires tools for managing group processes (Anandajayasekeram, Puskur et al. 2009). This skill set cannot be obtained through formal education alone but must be developed through a combination of formal education and practical experience (Klerkx, 2012). In Pakistan, a recent study has demonstrated the impact of improving farm advisor capacity and using a 'whole-family extension approach' (WFEA). The WFEA involves interdisciplinary training to the men, women and children of the farming household on the whole dairy-farming system. This resulted in on-farm practice change of recommended interventions and overall productivity increases up to 25-30% of smallholder dairy farming families (Warriach, et al. 2018). This study provided some foundation to establish AIS in the country. To integrate the successes of this approach within the wider livestock extension system of Pakistan, there is limited information available to understand the capacity building needs of farm advisors from the various organisations who play a role in this system. Therefore, this research aims to address the question; what are the skills, knowledge and learning required to integrate the WFEA within the current farm advisory services in Pakistan?

Methodology

2.1. The 'whole-family extension approach'

The present study builds on the WFEA which was previously developed with collaborating partners in Pakistan (Warriach, et al. 2018). This approach was based on the rationale that different family members are responsible for different aspects of the farm operations and, thus, would require different information. Females are most often responsible for milking, oestrus detection and calf rearing, males for agricultural farming operations, while children play a major role with calf rearing. Providing information to all family members stimulates informal discussion among family members over meals and during non-working hours. By stimulating awareness and discussion among family members, it was expected that an increase in on-going implementation of improved farm practices would be achieved. The role of female farm advisors is highly important in order to implement the WFEA because it is not appropriate for male farm advisors to interact with female farmers due to cultural norms in many communities.

This project used an action research (Carr and Kemmis 1986) approach and participatory methods to engage a multi-disciplinary research team, smallholder dairy-beef farming families, fam advisory service providers and policy makers in identifying opportunities for improvement and implementing participatory activities to achieve this integration.

2.2. Network of farm advisory services organisations

The project has engaged twenty-two organisations who are part of the pluralistic advisory system of Pakistan to support this innovation (including research, government, NGOs and private sector organisations) (Table 1). The project is supporting these organisations to establish the links, information flows and shared visions to ensure it will function as AIS as outlined by the World Bank (2006) .

2.3. Farm advisors training workshops

Each organisation designated up to four farm advisors to be part of a training program and community of practice workshop (three days) after every six months (from Jan 2018 until Dec 2020). Farm advisors technical background varies greatly depending upon the scope of their respective organisation including researchers from the University sector, veterinarians, veterinary assistants and agriculture graduates from the government and private sector, social mobilizers from the the NGO sector and various technical diploma holders. Organisations having both men and women as part of their farm advisory teams nominated at least one male and one female to participate in this collaboration. The remaining organisations have designated the available option either male or female to attend these training workshops. This includes training on various technical extension modules (Table 2), social mobilisation, gender mainstreaming, participatory communication skills and the opportunity to engage in a collaborative learning environment where individuals reflect on their own field experiences and the challenges they face. During each training workshop the project team covered two of the technical modules outlined in Table 1.

2.4. Field follow-up visits

Field follow-up visits were conducted by the trained project team members consisting of both males and females in both provinces the project was working in (Punjab and Sindh). These field visits occurred every six months. During these follow-up visits project team members are providing one-to-one mentoring to the farm advisors, monitoring and evaluation of the implemented activities. The project team also collected the data from each field follow-up visit from the farmers and farm advisors.

2.5. Conceptual framework

The framework by Prager, et al. (2017) was used for assessing advisory services based on a conceptual framework for analysing characteristics of advisory services as a component of the wider AKIS. This framework could therefore be expanded for developing country contexts, including criteria on: capacity building of farm advisors; advisors meeting the diverse needs of farmers; support beyond technology transfer and support to streamline organisational extension programs.

2.6. Data collection strategy

Qualitative data regarding capacity, management, advisory methods and quality of services provided was collected from 50 farm advisors using two approaches; (1) through two reflective focus groups where participants were divided into four subgroups including (research, government, NGOs and private sector organisations) having representation of each category of organisations during July 2018 and December 2018, at the community of practice sessions and (2) during field follow-up and mentoring visits after every six months. Data was collected by the project team based on the framework proposed by Prager, et al. (2017) for the evaluation of farm advisory services.

FINDINGS

The present study demonstrated that regular capacity building trainings of farm advisors on whole farming system is one of the key components to integrate the WFEA within the current farm advisory services in Pakistan. The overview of criteria for assessing advisory services of various farm advisory service providing organisations after the integration of WFEA have been presented in (Table 2) derived from Prager, et al. (2017). Findings related to the experiences of farm advisors with pluralistic extension in the study are presented under the following sections: capacity building of farm advisors, farm advisors meet the diverse needs of farmers, support beyond technology transfer and support to streamline organisational extension programs. The sections were derived from the theoretical framework by Prager, et al. (2017) and analysis of the qualitative data.

Capacity building of farm advisors

In the present study, evidence from reflection sessions showed that regular training of farm advisors is one of the key factors to strengthen the current farm advisory system of Pakistan. Most of the farm advisors mentioned that regular training programs helped them gain skills to build trust with communities and helped them to achieve their organisation's goals. Majority of the farm advisors mentioned that after participating in the farm advisor training workshops, they feel more technically sound, confident, resourceful and able to tackle extension challenges more effectively. Farm advisors from the private sector and NGOs found that the technical information provided was simple and highly applicable to smallholder farming communities; previously this type of material has not been readily available to them. Farm advisors from the private sector and NGOs actively participated because provision of farm advisory services is the part of main role of their job. During the second reflection session, majority of the farm advisors found that training component of social mobilisation and communication skills remained highly useful for building trust in developing relationships with farming communities and within their organisations. The results of present study align with a previous study where system-level farm advisory services were evaluated and 87% organisations found that regular training of farm advisors is an important component of a successful advisory service (Prager, et al. 2017).

Farm advisors meet the diverse needs of farmers

In the present study, evidence from reflection sessions showed that training on 'whole farming system' meet the diverse needs of smallholder farmers. Majority of the farm advisors from private sector and NGOs mentioned that they always have very limited knowledge and extension material to share with the farmers. Majority of the farm advisors that are part of this training program don't have technical background and furthermore, there was no mechanism to obtain the trainings opportunities during their routine job. Farm advisors have to consult with their senior management regarding various technical questions asked by the farming communities. "After getting these regular trainings now feeling much technical sound and confident and, in a position, to respond any question from the farming community that is why farmers start calling me Dr" (Farm advisor from private sector). Which mean the community has established their confidence on my technical advices.

In the present study, evidence from field follow-up visits with NGOs demonstrated that after practicing various innovative advisory methods (focus groups, participatory extension approach, farmer-to-farmer exchanges, demonstrations, individual farm visits) the WFEA helped to establish trust and a feedback mechanism with the farming communities. Due to this mechanism now, farmers can openly share their issues and looking for the solution from their organisation. The farmers working with one local NGO provided "the feedback to the higher management that they should be taught about the technology of local seed production of Rhodes grass because it is very expensive" (Farm advisor from local NGO). That organisation communicate to the project team regarding this technology of local production of Rhode grass seed. Project has now initiated one research trial to develop that technology.

Support beyond technology transfer

Based on the qualitative data captured during the reflection sessions, the farm advisors from private sector and local NGOs shared that the WFEA helped to strengthen their linkages with the communities. Previously, farm advisors only interacted with the communities regarding their organisational mandatory targets which were primarily transactional, like milk collection, seed sale or credit provision. After receiving social mobilisation and communication training we have "started to spend more time with communities to provide them support beyond our routine job targets" (Farm advisor from private sector). Previously we have "limited topic to discuss with communities" (Farm advisor from private sector). After getting these trainings we started "discussing to establish community based various entrepreneurs' models" (Farm advisor from local NGO). Based on the qualitative data captured during the second reflection session, the farm advisors from local NGOs shared that their organisations are utilizing "WFEA as an effective tool for the poverty alleviation" (Farm advisor from local NGO).

Support to streamline organisational extension programs

Based on the qualitative data captured during the reflection sessions, farm advisors shared that overall the relationship between (1) their organisation and farming communities and (2) their immediate supervisors and farm advisors have been significantly improved after adopting the WFEA. Many farm advisors from private companies shared that previously they were providing extension services to the farmers with limited scope as they were not aware about the significance of various components of an effective extension program. During the reflection sessions, few farm advisors shared that "now they realize the significance of female extension staff in order to implement WFEA and to achieve the on-farm practice change goals" (Farm advisor from private sector). Farm advisors from International research organisation mentioned that "their higher management realized the significance of female extension staff and they would like to involve two female extension staff in future training workshops" (Farm advisor from International research organisation). Farm advisors from government department mentioned that "previously their focus was always on the treatment of animals now they have initiated regular extension activities like farmers discussion groups and school program to educate children regarding the best farming practices" (Farm advisor from government).

Few farm advisors from the NGOs having non-technical background shared that they have "established good working relationship among the other farm advisors involved in this program so that they can consult the most relevant person within the network whenever they have any particular issues" (Farm advisor from local NGO). For example, veterinarians are specifically contacted for animal disease outbreak/treatment or when farmers are requiring technical information. In this way, the project has connected these various organisations with multiple objectives and enabled them to work towards achieving the common goal of improving the livelihood of smallholder farmers.

DISCUSSION

The present study identified the key components to strengthen the farm advisory services in Pakistan. Improving farm advisor's capacity to play the role of innovation broker is the most critical step to establish innovation system in developing countries. Data from this study identify that the diverse educational backgrounds and field roles along with a lack of regular capacity building trainings of farm advisors on whole farming system are the key constraints to integrate the WFEA within the current farm advisory services in Pakistan. Many other South Asian countries, like India and Bangladesh have taken initiatives to transform roles of the agricultural extension to support innovation as a collective process of putting knowledge into practice, and achieving multistakeholder social, economic and environmental goals. Public-sector extension agencies and extension workers are finding it difficult to translate their roles from the classical model of agricultural extension to the AIS perspective (Rivera and Sulaiman 2009). This implies that more empirical research is needed to understand the capacity challenges of a farm advisor to effective partner and facilitator of innovation.

Pakistan's agricultural industries are evolving rapidly to service the needs of millions of the smallholder farmers. The Government invests in infrastructure and human resources in their departments of agriculture, livestock and research institutions as a high priority. The current high-priority projects focus is on short-term goals with limited scope. There is need to establish country wide Agricultural Innovation System (AIS) which is a process of co-production of new knowledge, products and processes applied to provide benefits in society and requiring technological, social, economic and institutional change (Hall, et al. 2004). A systemic understanding of innovation within an agricultural innovation systems perspective considers research and extension actors (the research, development & extension system or RD&E) as part of a broader network of actors that include practitioners like farmers and community members, processing sector groups, agricultural traders, retailers, policymakers, consumers and civic advocacy groups as sources of innovation (Knickel, et al. 2009). A program of this nature has great potential to significantly increase on-farm efficiency and livelihoods of millions of smallholder farming households across Pakistan.

CONCLUSION AND RECOMMENDATION

The results of this study conclude that regular capacity building trainings of farm advisors on the whole farming system, integrating female farm advisor, establishing trust and feedback mechanism among various actors involved in process, training on social mobilisation and communication skills of farm advisors are the key components to integrate the WFEA within the current farm advisory services in Pakistan. A program of this nature has great potential to significantly increase on-farm efficiency and livelihoods of millions of smallholder farming households across Pakistan.

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ANNEXES

Table 1. List of the extension organisations engaged with the dairy-beef project of Pakistan

Organisations	Type/Mandate
University of Veterinary & Animal Sciences, Lahore	Academia, Research, Extension
Sindh Agriculture University, Tandojam	Academia, Research, Extension
University of Sargodha	Academia, Research, Extension
Centre for Agriculture and Bioscience International	Research, Development, Extension
National Agricultural Research Centre	Research
Farm Dynamic Pakistan	Private sector, Extension
Shakarganj Foods Products Limited	Private sector, Extension
Fauji Foods Limited	Private sector, Extension
Engro Foods	Private sector, Extension
Haleeb Foods Limited	Private sector, Extension

Matra Asia (Pvt) Ltd	Private sector, Extension
Nestle Pakistan	Private sector, Extension
Livestock & Dairy Development, Punjab	Government, Extension, Research
Livestock & Fisheries Department, Sindh	Government, Extension, Research
National Rural Support Program	NGO, Development, Extension
Lodhran Pilot Project	NGO, Development, Extension
Management & Development Foundation	NGO, Development, Extension
Rural Education and Economic Development Society	NGO, Development, Extension
World Wide Federation	NGO, Development, Extension
Potohar Organization for Development Advocacy	NGO, Development, Extension
Sindh Agricultural and Forestry Workers Coordinating	NGO, Development, Extension
Akhuwat Foundation	NGO, Development, Extension

Table 2. List of the extension material developed by ASLP dairy project for smallholder dairy farmers

Modules	Fact sheets
Animal husbandry	Basic husbandry principles
Basics of animal nutrition	Basics of animal requirements
	Nutritional requirement according to age, weight and production
	Ration formulation
Calf rearing	Calf management
	Calf diseases
	Calf fattening
Animal reproduction	Principles of animal reproduction
	Reproductive disorders
	Importance of feed for reproduction
Dairy breeds and their selection	Different breeds of dairy animals
	Recommendations for the purchase of milking animal
	Selection of better productive animals

Ration formulation	Balanced feed for animals Total mixed ration (TMR) Urea molasses block (UMB) and mycotoxicosis
Improved fodder agronomy	Strategies to overcome fodder shortage Seed selection and preparation Summer and winter fodders Mixed cropping
Milk marketing and value chain	Cost of milk production Milk marketing options Milk value addition
Animal health	Deworming of animals Infectious diseases of animals and their prevention Mastitis prevention
Extension and mobilization	Communication skills Relationship building Community mobilization

Table 3. Overview of criteria for assessing advisory services providing organisations

Criteria	Type of organisation	Assessment (+ is being met, − is not being met)
Advisory organisations involved draw on diverse knowledge sources	Research	-
	Government	-
	NGOs	+
	Private sector	+
Advisory organisations cooperate to bridge potential knowledge gaps	Research	+
	Government	+

	NGOs	+
	Private sector	+
There is a stable or growing workforce of advisors	Research	-
	Government	+
	NGOs	-/+
	Private sector	+
Advisors receive regular training	Research	-
	Government	-
	NGOs	+
	Private sector	+
All relevant advisory topics are covered	Research	-
	Government	-
	NGOs	+
	Private sector	+
All client groups are covered	Research	-
	Government	+
	NGOs	-
	Private sector	-/+
A range of advisory methods are used	Research	-
	Government	-
	NGOs	+
	Private sector	-/+

DETERMINANTS OF FARMER'S DECISION TO JOIN A PARTICIPATORY EXTENSION PROGRAMME: A MIXED METHOD ANALYSIS OF NORTHERN IRELAND BUSINESS DEVELOPMENT GROUPS

Claire Jack[a], Adewale H. Adenuga[a], Austen Ashfield[a], Conall Mullan[a] and Michael Wallace[b]

[a] Agricultural and Food Economics Branch, Agri-Food and Biosciences Institute, Belfast, Uk
[b] School of Agriculture and Food Science, University College Dublin, uk

Abstract

Innovation, in terms of product, process and practice is now at the core of the global agricultural policy agenda. There is an increased need for farmers to become more innovative in what has become a changing agricultural environment requiring the increased adoption of advanced technologies and sustainable management practices in order to improve productivity. The purpose of this paper is to examine and analyse farmers' decisions in relation to joining and participating in a new approach to farm extension learning and advisory service provision; namely the Business Development Groups (BDG) scheme in Northern Ireland. The BDG programme focuses on facilitating 'peer-to-peer' learning at the farm level. The approach provides farmers the opportunity to discuss farm business challenges with other farmers and to draw on knowledge and experience within the group. Making use of data from both primary and secondary sources, this study employs a mixed method approach which involve an empirical analysis of quantitative and qualitative data to examine the factors influencing membership of the BDG programme. The results of our analyses show that larger, more intensive farmers who are keen to access information from other farmers to improve their business performance are most likely to participate in the BDG programme. The study contributes to the empirical literature as it provides a comprehensive analysis of factors influencing the decision to join participatory extension programmes using a mixed method approach. The results of the analysis will provide evidence to inform future policy development in the area of participatory extension programmes.

1.0 Introduction

Innovation at the farm-level, in terms of product, processes and practice, is now emerging as a core theme in the global agricultural policy agenda (Hooks et al. 2017, Singh and Bhowmick 2015). As farmers operate more and more in a competitive global markets, farm-level profitability increasingly depends on their recognition of the need to adopt new management practices and advanced technologies that will underpin sustainable farming systems. Central to increasing the innovative capacity at farm level are existing extension service providers who have an important role in facilitating effective extension services that encourage farmers to augment their skills and knowledge and embrace new technologies and best practices (Hennessy and Heanue 2012). Alongside this, effective extension programmes should provide an avenue for better communication of relevant research findings as well as innovations in order to bring about improved diffusion and adoption at farm-level (King et al. 2019, Läpple, Hennessy, and Newman 2013, Tamini 2011).

The international literature commonly identifies four major strands of agricultural extension methods namely: linear technology transfer, one-to-one advice, structured education and training and participatory extension methods (Black 2000, King et al. 2019, Esparcia 2014). National advisory programmes around the world have tended to adopt a range and combination of these methods in order to fulfil their farm- level extension remit.

The linear one-to-one basis using a top down approach has been the most dominant extension method for many years (Black, 2000). However, this approach has limitations firstly in terms of the extent of its coverage to farmers and secondly in its ability to take account of and be responsive to the current, more complex agricultural production environment which requires more innovative approaches. In a bid to overcoming these challenges, a new participatory advisory service provision for farmers namely the Northern Ireland Farm Business Development Groups (BDGs) was established in March 2016. The overarching goal of the programme is to increase farmers' access to agricultural extension services that will foster sustainable agricultural practices, improve farm-level productivity and ultimately increase economic performance at farm-level. The scheme focuses on facilitated 'peer-to-peer' learning, bringing farmers together to share knowledge and skills, help them improve their technical efficiency and business management skills and introduce them to new technologies and innovative ways of working. Previous research has shown that interactions and exchanges of knowledge from multiple sources especially from actors within the production value chain promotes the adoption of best production practices and new technologies which consequently improve farmers' productivity and income (King et al. 2019, Woodhill 2014)

The BDG scheme is a part of a wider programme, the Farm Business Improvement Scheme (FBIS), part funded by the EU through Pillar II of the Northern Ireland Rural Development Programme 2014 – 2020 (Department of Agriculture 2016). It employs a group approach to improve farm businesses performance; (allocation to groups is by main farm enterprise and farm location). Farmers participating in the scheme have their farm key performance indicators recorded and benchmarked to identify areas for potential improvement in performance. They also maintain an active business development plan, attend training events, and share benchmarking information with other group members. Each farmer hosts a group training event on their farm during the lifetime of the scheme and interactions are held under the guidance of a facilitator who bring in new ideas and foster innovation, particularly around the use of new technologies. Participatory extension approaches have previously been shown to give farmers improved access to local and expert knowledge, as well as developing well-functioning social networks which promote rural innovations (Esparcia 2014, Swan and Newell 2000, Klerkx, Aarts, and Leeuwis 2010). The implementation of the BDG programme in Northern Ireland emphasises relational processes including co-learning and reflexivity. It provides group members with the opportunity to discuss farm business challenges, and to be actively involved in a shared problem-solving process. The farmers meet formally at least eight times a year, providing them with an opportunity to talk about issues relating to their own farm business, including responses to wider market, policy and technology drivers. The participants are eligible to claim for costs associated with analytical services and an allowance of £600 for hosting a training event. The total government investment in the FBIS scheme as a whole is worth over £40 million (Department of Agriculture 2016).

The objective of this study is to explore and analyse the reasons around farmers' decisions to join and participate in the BDG programme in Northern Ireland using a mixed method approach (empirical analysis of quantitative and qualitative data). This research makes a unique contribution to the existing literature by providing a comprehensive analysis of the factors influencing the decision to join participatory extension scheme in a Northern Ireland context. The study examines the reasons why farmers chose to join or not join the BDG programme and identify ways in which the programme might be improved. We are not aware of any previous study that have employed the mixed method approach to analyse the factors influencing the decision to join participatory extension programmes. While a few studies on participatory extension programmes have been undertaken in the Republic of Ireland (Läpple and Hennessy 2015, Hennessy and Heanue 2012, Läpple, Hennessy, and Newman 2013) these studies focused mainly on the measuring the impact of the participatory extension programme. Only Hennessy and Heanue (2012) have analysed factors associated with membership of participatory extension programme but this research focused on just one enterprise group; dairy discussion groups. Our study cut across different enterprise groups and uses a mixed method approach (empirical analysis of quantitative and qualitative data) to provide a balanced analysis around the decision of different groups of farmers to join a BDG by creating additional insights into the perceptions and motivations of the members in the context of the programme being newly initiated. The mixed method approach is fast gaining popularity in the literature to provide answers to research questions focussing on personal, social and psychological variables (Triste et al. 2018, Wauters and Mathijs 2013). For example, Triste et al. (2018) employed the mixed method approach to explore the influence a sustainable farming initiatives (SFI) design characteristics may have on farmer motivation to participate in *Veldleeuwerik*,(a Dutch SFI programme). Also, Charatsari, Lioutas, and Koutsouris (2016) employed the mixed method approach to investigate farmers' motivational orientations towards competence development projects (CDP) and the needs that drive them to participate in such activities.

The exploratory analysis of the BDG programme which is a novel approach to participatory extension practices can also serve as a template of participatory extension programmes in other regions both nationally and internationally.

The remaining sections of this paper are organised as follows: Section 2 describes the methodology while section 3 explains data available. The results and discussion are presented in section 4 and finally, section 5 concludes.

2.0 Methods

2.1 Data

Data for this study was obtained from both primary and secondary sources. The primary data is obtained through an "entry level" survey which was undertaken for BDG participants and non-participants at the initial establishment of the programme. The survey questionnaire captured those factors which might influence a farmer's decision to join or not join a group and include close and open ended questions. The options from which the farmers were to choose from were carefully selected based on literature review and experience of the authors. In total 719 farmers completed the questionnaire over a 3 month period with a response rate of ~24% for the members of the BDG programme while 52 responses were obtained for farmers who are not members of BDG group. The primary data from the entry level survey was analysed to provide more insight into why farmers chose to join or not to join the BDG programme.

The secondary data were obtained from the Northern Ireland Farm Business Survey and the College of Agriculture, Food and Rural Enterprise (CAFRE) benchmarking data for the year 2015. While data for the members of the BDG group was obtained from the CAFRE benchmarking data collected annually from the members of the BDG programme (treatment group), data for non-members was obtained from the FBS data collected by DAERA Statistics and Analytical Services Branch. The CAFRE benchmarking and FBS data contains detailed information regarding the financial position of the farm business. Variables captured in both data sources and used for analysis are directly comparable.

These secondary data sets were modelled using Logistic regressions model, followed by a detailed analysis of the primary data aimed at providing insights around the decision to participate or not to participate in the BDG programmes. This include an analysis of sources of information about the BDG Scheme, attendance rate and ways of improving the programme.

2.1 Logistic Regression Model

The logistic regression is used to develop a regression model when the dependent variable is categorical (Cox 1958). It possess a dichotomous dependent (left-hand-side) variables coded as 0/1 (Adenuga et al. 2013). For this study, the dependent variable is coded 1 if the farmer is a member of a BDG group and coded 0 otherwise. The explanatory variables hypothesized to influence membership of the BDG group include: the utilised agricultural area measured in hectares, age of the farmers measured in years, herd size measured in cow equivalent and herd size squared also measured in cow equivalents. These variables were selected taking into account previous literature (Hennessy and Heanue, 2012) Due to data limitation we were unable to include more variables in the model. The empirical specification of the logistic regression model is presented in equation (1).

$$logit\ (p) = ln\left(\frac{p}{1-p}\right) = \beta_0 + \beta_i X_i \quad (1)$$

Where p is the indicates the probability of joining the BDG programme, β_i are the regression coefficients associated with the membership of the BDG programme and x_i represents the explanatory variables hypothesized o influence membership of the BDG programme.

3.0 Data and Descriptive Statistics

An overview of the farm characteristics of the members and non-members of the BDG programme is presented in Table 1. The analysis was undertaken using Stata 15.0. The results of the analyses showed a significant difference in farm characteristics between farmers participating in the BDG programme and non-participants. For example, considering the combined sample of farmers for members and non-members of the BDG group, it can be observed that farmers in the BDG groups have larger land areas (54.8 hectares versus 31.2 hectares), larger herd size (108.6 versus 50.5), are younger (47.7 years versus 54.6 years) and are the more profitable farmers (£901.4. versus £456 per hectare). The higher profitability of the BDG farmers may be associated with the fact that farmers who join participatory extension programmes are more motivated to improve farm-level profitability and therefore are more likely to adopt new technologies and best farm management practices (Hennessy and Heanue, 2012). This observation supports previous studies in the literature, for example Davis et al. (2012) and (Läpple, Hennessy, and Newman 2013) also found initial differences between participants and non-participants of participatory extension programmes.

Table 1: Descriptive statistics on characteristics of the BDG and Non BDG Farmers, 2015

Variables		BDG Farmers		Non BDG Farmers	
All Enterprises	Description and unit	Mean	SD	Mean	SD
Allocated Land area	Hectares of area	54.8	44.4	31.2	24.2
Age of farmer	Years	47.7	13.6	54.6	12.1
Size of herd	Cow equivalent	108.6	81.3	50.5	48.2
Gross margin	£/hectare	901.4	688.9	456.51	415.80

4.0 Results and Discussion

The result and discussion section is reported in the two following subsections. The first subsection focuses on the result of the logistic regression model presented in Table 2. The result explains the factors influencing farmers' decision to join BDG groups. This is followed by a discussion of the results of the qualitative analysis of the membership of the BDG programme.

4.1 Determinants of farmer's decision to join the BDG programme

The results of the logistic regression analysis showing the parameter estimates and their respective marginal effect (the effect of a unit change in each explanatory variable on the probability of participation in the BDG programme) is presented in Table 2. The likelihood ratio statistic suggests that the model is significant ($p<0.01$). We found the herd size and its squared term were statistically significant ($p<0.01$) with positive and negative signs respectively. Variables with a positive coefficient increase the probability of participation while those with a negative coefficient decrease the probability of participation. Specifically, the results implies that farmers with larger herd sizes are more likely to participate in the BDG programme although at a declining rate given the negative sign and the statistical significance of the herd size squared term. The increase of herd size by one unit will increase the probability of participation in the BDG programme by 0.7 per cent. We also found land area to be positively associated ($p<0.1$) with participation, indicating that farmers with larger land area are more likely to join the BDG group. An increase in land area by one hectare increases the probability of participation by 0.2 per cent. On the other hand, we found a negative and statistically significant relationship between the age of the farmer and the decision participate in the BDG programme. This indicates that the younger farmers have a higher probability of joining the BDG group compared to the older farmers. A one year increase in the age of the farmer will decrease the probability of participation in the BDG programme by 0.6 per cent. Similar results were obtained by (Hennessy and Heanue 2012) in which they found both land and herd size to be statistically significant determinants of the decision to join a dairy discussion group.

Table 2: Logit regression model results

Variable (N= 703)	Coefficient	Std. Err.	Z-Statistic	Marginal effect
Constant	0.28602	0.40326	0.71	
Herd Size	0.03078***	0.0039	7.99	0.0071
Age	-0.0278***	0.0069	-4.04	-0.0064
Land Area	-0.01*	0.0057	-1.72	-0.0023
Herd Size^2	-0.00004***	7.72e-06	-5.08	-9.10e-06
Log likelihood	-386.2046			
LR chi2(4)	178.35			
Prob > chi2	0.0000			
Pseudo R2	0.1876			

***, **, * Significant at the 1%, 5%, 10% level, respectively

4.2 Results of Qualitative Analysis of the Decision to join or not to join the BDG Groups

The results of the primary data analysis in respect of reasons why farmers decide to join or not to join the BDG programme is presented in Table 3 and 4 respectively.

4.2.1 Reasons for Joining the BDG Programme

In the entry level survey, farmers who are participating in the BDG programme were asked to rank the factors that influence their decisions to join the BDG programme based on degree of importance. The results of the analysis presented in Table 3 showed that the most important reason why farmers decided to join the BDG programme was because they wanted to learn from other farmers. This result confirms that farmers place value on the opportunity to draw on the knowledge and experience of other farmers. Another important reason why farmers decided to join the BDG programme was to access other schemes. This may probably be connected with the initial perception at the start of the programme that BDG membership would be a pre-requisite for accessing other government funded schemes and supports. This is understandable as participation in the scheme gives the farmers greater access to information through the facilitators and other farmers which enables them to easily access other schemes such as the "capital grant" scheme compared to farmers that are non-members of the BDG programme. This buttresses the results of the quantitative analysis which shows that farmers with larger farm sizes and probably more commercially oriented are more likely to join the BDG programme. Another interesting result is the ranking of 'access to annual payment' as the least important. This might indicate that the majority of the farmers that join the BDG programme do so to be able to improve their farm performance rather than the motivation of obtaining the payment they will receive when they join the programme.

Table 3: Reasons for Joining the BDG Programme

Reasons	Degree of Importance	**Rank**
Accessing CAFRE advice/information	4.15	4th
Opportunity to engage socially with like-minded farmers	4.24	3rd
The annual payment	3.85	5th
To access other schemes/future schemes	4.29	2nd
To learn from other farmers	4.55	1st

Key: 1 = not important 2 = Less important, and 3 = important 4 = Very important

4.2.2 Reasons for not joining the BDG Programme

The results presented in Table 4 gives a summary of the reasons provided by non-members of the BDG programme as to why they did not join a BDG group. Almost 27 percent of the surveyed respondents said they did not participate in the BDG programme because they were not aware of it at the time it was introduced. This highlights a need for improved communication of the existence and potential benefits of the programme to raise awareness among the farming population. Our analysis of the sources of information regarding the programme showed that Newspapers/Press/Media were the most popular means of communicating the programme to farmers (Table 5). Twenty-five per cent of respondents indicated that they did not participate in the programme because they never saw it as relevant to their farm business. This result corroborates the results of the quantitative analysis where it is found that farmers with larger herd size and land area and who a more commercially oriented have a higher probability of participating in the BDG programme. The findings highlight that the method of communication to promote the BDG programme and its membership requires careful consideration to establish a good level of uptake.

Table 4: Reasons for not Joining BDG

Reason	Frequency	Percentage
I thought it would involve too much work	3	5.77
Did not see it as relevant to my farm	13	25
I am already involved in the Farm Business Survey	4	7.69
I did not apply on time	2	3.85
I didn't like the idea of sharing farm business/financial information with other farmers	7	13.46
I was not aware of it at the time	14	26.92
Would not have been able to take time away from the farm	6	11.54
Other	3	5.77
Total	52	100

Table 5: Sources of Information about the BDG Scheme

	Frequency	Percentage
CAFRE advisors	210	29.17
DAERA website	89	12.36
Family member	14	1.94
Newspapers/Press/Media	294	40.83
Through involvement in another scheme	24	3.33
Through the farming unions	19	2.64
Other farmers	62	8.61
Others	8	1.11

4.2.3 Average Attendance at BDG Meetings

The farmers participating in the BDG programmes are expected to attend at least 8 meetings within a year. The results presented in Table 6 showed that the average attendance of farmers at meetings for the first and second year of BDG membership. The results show that attendance at the meetings was relatively high.

Table 6: Attendance rate

BDG groups	2016/2017 (%)	2017/2018 (%)
Dairy	86.9	82.0
Sheep	89.6	85.0
Cattle	91.9	84.0
Beef	90.0	84.1

For the dairy business development group for the year 2017/2018 about 82 per cent of the participant have more than 75 per cent attendance and about 30 percent has 100 percent attendance. For sheep, 88 percent have at least 75 percent attendance and as much as 32 percent has 100 percent attendance. For the beef BDG group, 87 per cent has at least 75 per cent attendance and as much as 34 per cent has 100 percent attendance. For the cattle group, about 86 percent of the participants have more than 75 percent attendance and as much as 28 percent has 100 percent attendance.

4.2.4 Areas of Improvement for the BDG programme

As part of the entry survey, respondents were asked to identify areas of improvement for the BDG programme. Given that it was an open ended question, different responses were obtained from the farmers in the BDG programme. The responses were analysed and grouped into 15 headings as presented in Table 7. From our analysis, we found that 24 per cent of the farmers believe that no change is required as they are satisfied with the current operation of the programme. However, close to 20 per cent of group members believe more in-depth diverse and technical information should be provided at BDG meetings. About 9 per cent of the farmers also indicated that more meetings and farm visits per year will enhance the benefits gained from BDG membership.

Table 7: Identified Areas of Improvement of the BDG programme

Areas of improvement	Frequency	Percentage
Flexibility in group rules	21	2.91
More outside speakers and workshops	19	2.61

Improved diversity in group composition and meeting schedule	31	4.3
No change is needed	173	23.99
Get qualification for attendance	8	1.11
More Farm Visits and Meetings per year	65	9.02
Improved social interaction among members and between groups	57	7.91
Review progress made by members/Revisit issues raised on farm visits	26	3.61
Link membership to grants	6	0.83
More members	18	2.49
More in-depth , diverse and technical information	142	19.69
Continue attendance payment	37	5.13
UK/Ireland trips	20	2.77
Group winter meetings off farm	26	3.61
N/A	72	9.99

5.0 Conclusion

In this study, we employed a mixed method approach to elucidate the key drivers of farmer participation in the Northern Ireland BDG programme. The approach provides a comprehensive evidence of farmers' decisions to join or not to join a specific peer-to peer learning extension service, namely the BDG programme. From the results of the analysis, it can be concluded that herd size, land area and age of the farmer are significant factors influencing the decision of the farmers to join the BDG programme. Those farmers with larger farms (land area farmed) and who are younger demonstrate a greater willingness to join and participate in the BDG programme with the aim of raising the level of their farm performance. The results also show that farmers value the opportunity to obtain and share relevant information and discuss their farm business with other farmers; this ranks first among their reasons for joining the BDG programme. Although farmers were being paid for participating in the BDG programme, for most of the farmers, being paid was less important compared to the opportunity to share farming information with other farmers. This is in line with those of previous studies, for example Charatsari, Lioutas, and Koutsouris (2016) who stated that participation in competence development projects (CDP) is influenced by farmers' Willingness to cover their needs for autonomy and competence, rather than external factors. This might however require further research as a study by (Läpple and Hennessy 2015) has shown that farmers perform better when they did not receive incentives to join participatory extension group compared to when they were given incentives. In line with the results of the study, suggested improvements that could be made to BDG programme would be to explore a wider range of technical information in a more in depth way. There was also interest in increasing the number of meetings, in particular farm visits.

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ENABLING FARMERS' CONTINUOUS LEARNING THROUGH SOCIAL LEARNING PRACTICES - THE ROLE OF INNOVATION SUPPORT SERVICES

Lisa Blix Germundsson, Magnus Ljung

Swedish University of Agricultural Sciences, Department of People and Society, National Competence Centre for Advisory Services, Sweden

Abstract

Agricultural innovation policy increasingly emphasises farmers' continuous learning in multi-actor settings for knowledge development and innovation. The aim of this paper is to critically analyse the structural conditions for farmers' involvement in lifelong learning, and the role of innovation support services in supporting this. Within an exploratory case study approach, interviews with key stakeholders were analysed using a practice-based approach. The findings show that the overall structures and incentives enabling multi-actor learning opportunities of farmers and other actors are too weak. The practical implications are that there is a need to form working approaches that systematically build and uphold multi-actor networks, and innovation support services have a key role in this. The theoretical implications include the use of a practice-based approach, where the concept of practice offers a bridge between the structural conditions and the learning processes among involved actors.

Introduction

Contemporary agricultural innovation policies promote farmers' continuous learning in multi-actor settings for knowledge development and innovation (EU 2020; OECD 2019). It has been claimed by both the scientific community and policymakers that farmers' continuous learning and innovation is principal to the productivity and sustainability of agriculture and rural areas (EU SCAR 2019).

This claim is supported by several arguments. Firstly, the pace of current societal development is so fast that an on-going analysis of the surrounding world is required (Klerkx 2020). At the same time, the personal learning environment has changed dramatically due to new technological opportunities (Dabbagh and Castaneda 2020).

Secondly, the types of knowledge needed to solve the complex issues of agriculture are diverse and local (Leeuwis 2000). This requires transdisciplinary cooperation between farmers, advisers, researchers and other experts, working interactively through experiential learning, learning in groups and on-farm research (ibid).

Thirdly, the focus of continuous learning has shifted from subject specific skills towards more generic skills, i.e., the capacities needed to continue learning (Tilbury 2011). A recent literature review found the vital skills for life-long learning in agriculture to be; systems perspective, knowledge integration, building and maintaining networks and learning communities, and subject-specific skills (Sørensen et al. under review).

Policymakers and researchers have responded to these needs. Several approaches fostering multi-actor learning, and co-innovation have been developed and implemented (Cerf et al. 2000; Fieldsend et al. 2021). However, it still seems difficult to find a robust and generic model proven to be effectively scaled up and out (cf. Wigboldus and Leeuwis 2013). Despite the substantial scientific evidence and policy efforts, there are still challenges to farmers' involvement in continuous social learning at a general scale. According to Moschitz et al. (2015), many agricultural knowledge organisations are still locked into a science-driven linear paradigm of technology transfer. Oreszczyn et al. (2010) claim that the gap between scientific research and the support available to farmers is increasing, as research focuses on the scientific community and policymakers, rather than farmers.

These challenges call for a deeper understanding of the enablers and disablers of farmers' involvement in learning processes. In order to do this, we aim to critically investigate the structural conditions of farmers' involvement in continuous learning, and the role of innovation support services, such as advisers, in this. Advisers are being challenged by new expectations of handling interactions between heterogeneous actors, implying a paradigm shift from the transfer of knowledge to facilitators of knowledge development (Blackmore 2010; EU SCAR AKIS 2019).

To address this aim, we use the case of the horticultural industry in Sweden. Its focus on market competitiveness and the scarce resources for research and innovation make it an interesting case to employ for the investigation of the study's main premise. The study applies a practice based approach, focusing on people's recurrent activities that constitute their every-day social practices (Nicolini 2012). The concept of social practices offers a bridge between the structural conditions and the learning processes among involved actors.

The remainder of the paper is structured as follows. First, we frame the study with a brief overview of existing literature on the social dimensions of learning in an agricultural context. Secondly, the choice of case study is explained, and the methods for data collection and data analysis are introduced. The results of the empirical study are presented in the third section, followed by an analysis and discussion. Finally, we conclude our main results and provide suggestions for implications for practice and policy makers.

Social learning in an agricultural context

Learning - a social and participatory process

Collaborative, community-based and transdisciplinary learning, dialogue, and deliberation have long been described as desirable, even necessary, approaches to managing socio-ecological challenges (cf., Wondolleck and Yaffee 2000:23; Chang et al. 2020). This notion is based on findings in many fields; ideas about deliberation and participatory democracy (Dryzek 2010), the importance of local and tacit knowledge in sustainable natural resource management (McDonagh and Tuulentie 2020), the processes of experiential learning, adaptive management and institutional change (Rist et al. 2013), as well as interactive innovation and co-innovation (EIP-Agri 2015).

The practical arguments for farmers' involvement in knowledge development are many (Ljung 2001). Firstly, when developing management strategies adapted to site and cultivation-specific conditions, farmers' experiences are needed. Secondly, farmers have to be motivated, perceiving knowledge development as meaningful for them to participate in, learn and change their practices, and thirdly; one can argue that it is the farmers' democratic right to be able to participate in future policies and decisions that will affect their livelihoods. Collaborative processes might also be important for strengthening the individual farmer's social conditions, recognition and entrepreneurial skills (Nordström Källström and Ljung 2005; Ljung 2021a). Involving farmers and other stakeholders in social learning activities will contribute to the above-mentioned societal ambitions, but only if this involvement has certain qualities.

Farmers' experiential and social learning

To create the right preconditions for social learning, the basic principles for adult learning need to be considered. According to Vella (1994) there are 12 fundamental principles for adult learning, for instance, understanding the participants needs, a sense of safety, focus on praxis (action with reflection), immediacy of the learning outcomes, working with smaller groups, and accountability. It is the cumulative effect of all these principles that will allow dialogue to flourish and concrete measures to be implemented (cf. Daniels and Walker 2000). The creation of new knowledge is a continuous, spiralling conversation between explicit and tacit forms of knowledge (Nonaka 1994). Such learning hasthe ability to nurture and is necessary to facilitate new spaces organised for social learning (Wals 2007).

More specifically, five critical factors for learning in farmers' groups have been identified (Millar and Curtis 1997):

group autonomy,

effective facilitation,

the integration of information,

experiential learning and

ongoing relationships.

These factors are as valid and equally important when supporting social learning groups involving a broader range of stakeholders, such as farmers, advisors and researchers. Clearly, there is a strong foundation for approaches focusing on broad participation, systemic thinking and action, and critical assessment of existing social order; not least how scientists, advisors and farmers organize themselves and interact within the agri-food system.

It is important to keep in mind the fact that there is no one-size-fits-all approach to farmers' and other stakeholders' involvement. Different methods and tools must be prudently combined. In fact, learning and decision-making processes on complex issues will span different activities at different points in time (Ljung 2021b). Although adhering to some guiding principles (Brouwer and Woodhill 2016), the actual choices made regarding process design depend on the phase and goals of the anticipated work and the unique context.

Social learning for knowledge development and innovation

Raymond et al (2010) argue that many of the new approaches suggested aim to:

integrate knowledge held by academic researchers across disciplinary boundaries, and non-academic participants,

promote common understandings of shared problems and challenges,

utilise participatory research methods to enhance the validity of knowledge elicited in research and to increase the inclusion of stakeholders in decision-making,

implement iterative processes of knowledge creation and feedback to science or decision-making, and

integrate knowledge across a variety of spatial and temporal scales.

Successfully integrating different knowledge traditions, such as scientific and local knowledge, means putting research findings in a whole-farm context, along with integrating codified and tacit knowledge (Ingram 2008; Schneider et al. 2009; Sumane et al. 2018). Enabling experiential learning is supported by practical experiments, such as field trials, as they serve as a basis for discussion and learning (Hamunen et al. 2015; Prager and Creaney 2017). Finally, building and withholding strong relations among the actors is necessary for the sense of belonging and commitment among both farmers, advisors and scientists (Röling and Wagemakers, 2000). Together, these factors enable the emergence of new communities of practice (Blackmore et al. 2010) with a focus on developing new knowledge and innovations.

Social learning resulting in co-production of knowledge between farmers, advisors and scientists is essential for jointly moving towards more sustainable agriculture (Schneider et al 2009). Farmers are empowered in groups, rather than individually (Dolinska and d'Aquino, 2016), as these groups provide motivation and a structural base for farmers to identify and deal with their own needs for new knowledge and innovation (Coutts et al. 2005). Hence, such groups can provide a basis for researchers' engagement with farmers around meaningful research projects, contributing to continuous learning as well as sustainable innovations.

Method

Case selection

Swedish horticulture is a small industry in an international context, its share in 2018 of European production being 0.8% of vegetables and horticultural products, and 0.3% of fruit (EU 2019). International pressure has caused horticultural farms to become larger, fewer, and more specialised (Statistics Sweden, 2020). There is, however, rising interest in small scale vegetable farming vying for consumer preferences for local produce (Drottberger et al. 2021).

Over the last few decades, the number of people working in horticultural advisory services and field trials in Sweden has shrunk significantly. Advisory services are currently private and restricted to a few regions and plant cultures. Supplier firms have increasingly taken a role as the knowledge partners of farmers (Yngwe 2013). At the same time, horticultural research has changed from being state funded to a partly industry financed knowledge market of fewer resources (von Bothmer et al. 2018). Only a few researchers still work with applied horticulture, as the incentives for researchers to engage with applied projects are insufficient (Glynn et al. 2018). The communication between advisory services and research organisations is generally low within the domestic agri-food system (OECD 2018).

In summary, the Swedish horticultural industry has an emphasis on market competitiveness and, at the same time, scarce resources for applied research and advisory services. This implies a high demand for new knowledge and innovation, yet with few resources to deploy, making it an interesting case for investigating this study's main premise.

Research approach

This study sets out from the claim that structures form human actions, as both physical and social structures influence human daily practices (Giddens, 1984; Nicolini, 2012). Reciprocally, these structures are shaped by the recurring activities of people, as human actions in turn affect structures (ibid). For example, farmers have both physical structures, e.g., farm size and soil types, and social structures, e.g., family members and employees, embedded in the make-up of their farm business. These structures influence the daily operations and practices performed at the farm, and vice versa.

The study employs a practice based approach, focusing on what people do on a daily basis, their recurrent activities that constitute their social practices. Social practices are seen as reappearing activities that are meaning-making, identity-forming and order-producing (Nicolini 2012). The study of practices reveal the meanings, motivations and implicit knowledge underlying human actions (Bueger 2014). However, as people carry out their daily social practices, space is always left for creativity and initiatives. Social practices constitute the background against which people can take initiative and create new things, ideas and actions (Feldman and Worline, 2016).

To guide the collection of data, we used the concept of functions as a means of structuring the inquiry into the social practices connected to social learning and innovation. Functions can be defined as key sub-processes of the overall innovation process (Bergek et al. 2008). Several sets of functions have been assigned to agricultural knowledge and innovation systems, see Bachmann (2000:19) for an overview. In addition, several studies set in agricultural contexts have used the functional dynamics concept developed for technological innovation systems, by Hekkert et al. (2007) and Bergek et al. (2008). As a function can be carried out in many ways, it opens up the opportunity for the respondents to define it for themselves and thereby revealing the underlying meanings and motives of their practices.

Block no	Description	Questions	Sources informing the questions
1	Identification and articulation of possibilities or problems	How it usually happens, who is involved, incentives for doing this, etc.	Nagel 1980; Bachmann 2000; Hekkert et al. 2007; Bergek et al. 2008
2	Generation of new knowledge	Motives for doing this, how this is done, who is involved, etc.	Nagel 1980; Bachmann 2000; Hekkert et al. 2007; Bergek et al. 2008
3	Operationalisation of new knowledge	Motives for doing this, how is this done, who is involved, etc.	Nagel 1980; Bachmann 2000; Nonaka 1994
4	Knowledge exchange and dissemination	How this is done, what sources, if respondents share their knowledge, how, to whom, and why.	Nagel 1980; Bachmann 2000; Hekkert et al. 2007; Bergek et al. 2008; Rogers 2003
5	Creation of necessary resources for developing and testing new knowledge	How this is done, who is involved, and why.	Hekkert et al. 2007; Bergek et al. 2008
6	Guidance of the search	How do you know the direction in which you should develop your operations, what influences the direction of your attention. How this is done, who is involved, and why.	Hekkert et al. 2007; Bergek et al. 2008
7	Evaluation, monitoring of the work	Motive for doing this, how this is done, by whom, when.	Nagel 1980; Bachmann 2000; van Mierlo et al. 2010

Table 1. Overview of interview guide.

Data collection and analysis

The mapping of the focal practices was guided by the case study and approached through:

desk research of databases and documents, and identification of involved actors as a base for making an informed selection of actors for interviews.

The initial desk research included a thorough search in databases and revealed that vegetable production on arable land and fruit orchards accounted for nearly 75% of the total horticultural production area (Statistics Sweden, 2018), and constituted substantial parts of the research projects carried out in horticulture. The gathering of relevant reports and documents primarily gave an insight into the historical conditions leading up to the current situation. It served as a basis for creating a detailed picture of actors, networks, institutions and technologies prevalent in the fruit and vegetable sectors.

The actors selected for interview were identified on the basis of the initial desk research. The goal was to create a representative sample. The fruit and vegetable farmers where distributed in the south and west parts of the country, and were a range of experience levels, from newcomers to experienced growers. The following actors were interviewed in 2019-2021, see table 2.

Actor	Number of respondents	Main orientation	Regional/National
Farmer	12	Fruit (n=3) Vegetables (n=9)	South region (n=6) West region (n=6)
Advisor	5	Vegetables (n=5) (No domestic fruit advisor at the time)	South region (n=3) West region (n=2)
Producers' organisation/ farmers' customer	4	Fruit (n=2) Vegetables (n=2)	South region (n=3) West region (n=1)
Innovation coordinator	2	Both fruit and vegetables	South region (n=1) West region (n=1)
Researcher	7	Fruit (n=4) Vegetables (n=3)	National
Policymakers, national agricultural authority	4	Both fruit and vegetables	National
Farmers' supplier	1	Both fruit and vegetables	National
Farmers' union	2	Both fruit and vegetables	National

Table 2. Specification of interviewed actors (n=37)

All interviews were transcribed, read carefully, and fed into a computer based analytical tool. In the first round, the data were sorted according to an actor analysis. The actors' sources of and practices related to learning and innovation were analysed in detail. This analysis was discussed in depth between the authors, and resulted in a second round of sorting of interview excerpts, cutting across the actor analysis and responding to some of the functions described in table 1.

Results

Identification and articulation of possibility or problem

The horticultural farmers were interested in new knowledge mainly concerning their production, such as plant protection, weeds, fertilising, precision farming and technology in general, new varieties, storing and packaging. Many of the farmers' needs emanate from market requirements, as customers and market actors had demands concerning what to grow, the quality and other properties of their products, delivery requirements and pricing.

The farmers articulated their ideas, problems and needs when appropriate, in contact with other actors such as their advisors and suppliers. In addition, a farmers' organisation developed a research strategy based on the ideas and opinions of their members, in order to clarify their research needs and hoping to influence research funding priorities. They also collect plant protection needs from their members yearly and communicate these to suppliers and advisers. Advisers and researchers referred to a general analysis of their surroundings for new ideas.

Generation and acquisition of knowledge

When farmers spoke about their search for new knowledge to develop their operations, neighbours and colleagues were often mentioned as important sources of knowledge and inspiration. Support from colleagues was especially pronounced when starting with horticultural crops (e.g., from those with previous experience of the agricultural crops), and when adding new crops or new production methods.

The farmers' experience of research contacts varied greatly. On the one hand, respondents voiced a perception that farmers do not have the time to think about research, as they are already fully occupied running their operations, and there is not much domestic research on horticultural production anyway. On the other hand, farmers who had their own experience of involvement in research studies or hosted research trials, were more positive towards such contacts. Although it was perceived as burdensome at times, they enjoyed the dialogue with the researchers and felt that useful results were gained.

The responding researchers reported that research grants were generally directed towards understanding the basic mechanisms of certain phenomena, rather than practice-oriented issues. In addition, working with research built on field trials is time-consuming and comes with several sources of uncertainty. Therefore, it was generally regarded as easier and safer to stay in the laboratory.

The use of research approaches that involve stakeholders, were regarded as interesting by the researchers, albeit time-consuming. Participatory approaches were said to work best if researchers could work in teams in order to maintain continuity and trust with the participating farmers. However, it was seen as difficult to find the funding needed for long-term team-work of practice-oriented research. Nevertheless, this quote illustrates the interest from the respondent in involving stakeholders in research projects.

"When you work with growers and advisers, and you see them all fired up by the joy of discovery /…/ that's probably why I´m still working with this." (Researcher 2)

One of the respondents had worked as a facilitator of several research projects with a participatory approach. While researchers usually look at a question in depth in order to understand underlying factors, the farmer has the holistic role of putting the findings into the farm context. To include both views is a pivotal point, the respondent argued, for designing studies in a way that make concrete changes in farm practices possible. Furthermore, the adviser has an important role in participatory research approaches, as they have usually seen many farms and have a broad picture of how various things relate to different farm types. Moreover, advisers can play a key role in passing on new knowledge.

Operationalisation of knowledge

The researchers note that to operationalise research knowledge of basic mechanisms generally requires other types of funding sources than the traditional ones. This makes funding of practice-oriented research valuable in contributing to bridging the gap between research and practice. In addition, funding for practice-oriented studies can also be used for pilot testing or screenings that may constitute the basis for conventional research applications. However, the overall funding of horticultural production research is scarce.

Some advisers reported having good contact with researchers and good cooperation in specific projects. However, even those with good connections with researchers, reported a general lack of applied research. Much of their new knowledge was obtained from abroad, as domestic research is limited. Domestic field experiments are valuable as they provide regionally adapted knowledge as well as providing opportunities for the exchange of results with international advisory colleagues. Trial results from abroad cannot be directly translated to domestic situations, as the conditions may differ considerably.

The farmers' collegial relations were often referred to as cautious exchanges, where they were generally careful about sharing their knowledge with peers, due to market reasons. Despite this, organised peer-learning groups were seen as interesting. It was noted that peer-learning groups work best when someone knowledgeable, such as an advisor, leads the dialogue and facilitates learning.

"They [the facilitators] were important because they were very committed. Without them, it would not have worked /…/ In order for farmers to communicate well with others, they need learning groups like these because that is when everyone is tuned in to talking, exchanging and networking." (Farmer 4)

The quote illustrates the vital role of facilitators - in this case two advisers - of farmers' peer-learning groups, in order to create an open, sharing environment.

However, peer-learning groups were reported to be less common than previously. The reasons mentioned were fewer horticultural farmers, a perception of competition between farmers, or just the lack of anyone initiating a peer-group. The existing peer-learning groups were initiated mainly by farmer and producer organisations, or advisers.

Farmers who were members of the same producer organisation reported a more open attitude towards sharing experiences with each other, and that producer organisations encourage exchange between growers with similar cultivations, organise field excursions and study visits abroad. Generally, producer organisations do not provide their own advisory services, but there are some exceptions to this.

Knowledge exchange and dissemination

The previous state funded extension service with 40 horticultural specialists deployed across geographical regions and areas of expertise, was terminated in the 1990s. Private horticultural advisory services have been built up gradually over the last few years and are now available in the southern and western region for a few cultivations. The development towards larger and more specialised horticultural farms places higher demands on advisors. While domestic advisors are well acquainted with national conditions, legislation and regulatory compliance, international advisory services bring in comparisons to other countries.

The responding farmers reported talking to suppliers of seed, fertilisers, plant protection and equipment on advice related to the use of their products. The dialogue with suppliers was more pronounced in connection to large investments, or when the relationship was long-term. The supplier reported seeing their role as helping farmers to solve problems, rather than just selling.

Small-scale horticultural farmers, such as market gardeners, lacked advisory services altogether. They use informal peer networks, social media and the internet as important knowledge resources. A responding small scale farmer stated that he had set a clear intention from the start to foster a sharing attitude in his networks. He reasoned that farming at this very small scale is often an ideologically driven business, which makes people more open to sharing their knowledge freely. He also described growing demand as positively influencing attitudes towards knowledge sharing.

Analysis and discussion

This study uses a practice-based approach to investigate the structural conditions of farmers' involvement in continuous social learning and the role of innovation support services in this. To start with, while farmers continuously search for ways to improve their production, they were only ad hoc involved in social learning settings. The social learning opportunities were mainly represented by advisory and supplier contacts, and there was limited availability of peer-learning groups or involvement in research projects or field trials.

Advisers worked hard to keep up and develop their knowledge, with the aim of building and providing knowledge and advice on a commercial basis. They recognised the potential in multi-actor approaches. However, the existing advisory services were limited to certain regions and cultivations, and the resources for multi-actor modes of working were scarce.

While several of the responding researchers prioritized or would like to prioritize practice-oriented and participatory research approaches, they found themselves restricted by funding opportunities and incentives that push for scientific publications. There were structures that promote practice-oriented and multi-actor research and development efforts, such as intermediary organisations and advisors that work to link research and practice. Nonetheless, these structures have neither the resources nor the mandate to engage horticultural farmers in continuous social learning, at a general scale. Hence, the organisational division and differing incentives restrained the fostering of social learning and collaboration between actors more broadly.

While the social practices of the involved actors diverge, they also contain areas where interests aligned, or could be made to align. One such area is issues concerning improved field production, and this is where social learning and collaboration can be developed. Collaboration efforts need to start from the social practices of those involved. There is a need for building on existing practices, and implementing new ones where necessary, hence forming social learning practices.

The first step would be for actors to meet, as joint exploratory dialogues lay the foundations of collaboration between diverse actors. As peer-learning groups were perceived as having considerable learning potential, and the need for useful field trials has been emphasised, these can be part of a possible pathway forward. The role of innovation support services, such as advisors, is vital as they could carry the role of actively and purposefully facilitating such groups. Researchers and suppliers could be connected to the groups as resources.

Conclusions

The aim of this paper was to critically investigate the structural conditions of farmers' involvement in continuous social learning, and the role of innovation support services in this. Based on database searches, documents and interviews, the results illustrate the social practices of actors with differing motives and incentives, where multi-actor meetings rarely seem to happen. The results indicate a need for new approaches to farmers' continuous learning in multi-actor settings, and the vital role of advisory services in enabling this.

Using social learning processes as a means to not only manage complex issues and knowledge development but also to improve possibilities for continuous and lifelong learning among farmers has great potential. We suggest the creation of learning communities where farmers have a leading role, facilitated by advisors, supported by researchers, and including other relevant actors, such as suppliers. Field trials and practical experiments are suggested to act as organising devices, around which dialogues of joint learning and meaning making can be centred. Such groups can provide a basis for researchers' engagement with farmers around meaningful research projects.

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TRANSDISCIPLINARITY IN AGRO-ECOLOGICAL RESEARCH: AN EVALUATION FRAMEWORK

Alexandra Smyrniotopoulou[a], George Vlahos[a], Gerald Schwarz[b]

[a] Agricultural University of Athens, Greece
[b] Thuenen Institute of Farm Economics, Germany

Abstract

Acknowledging that sustainability issues demand new ways of knowledge production, the UNISECO H2020 project employs a transdisciplinary research approach in order to strengthen the sustainability of agro-ecological European farming systems. Transdisciplinarity is mainly performed through the Multi-Actor Platforms (MAPs), which are seen as the mechanism that brings together the project team and non-academic actors to encourage knowledge sharing and co-learning through participatory processes carried out in project's duration. The MAPs are established at the EU and the local (case study) levels aiming at co-constructing practice-validated strategies and incentives for the promotion of improved agro-ecological approaches. This paper is an attempt to review existing literature on the evaluation of transdisciplinary and participatory approaches in order to develop a monitoring and evaluation framework for assessing the process and outcome of interactions with the MAP members.

1. Introduction

The concept of sustainability demands an integrated and holistic way to address the interconnection between the biological systems and their physical environment, taking into consideration the social and economic factors that influence them (Blackstock et al., 2007). For this purpose, sustainability science uses practices, such as transdisciplinary and participatory research approaches that enable researchers of various disciplines to work together and collaborate with non-academic actors in order to solve complex sustainability problems (Lang et al., 2012). In a recent literature review (Holzer et al., 2018), focusing on how transdisciplinarity is defined in the context of socio-ecological research, transdisciplinary research is summarized as follows:

addresses real-world problems recognized at the same time by science and society (Hirsch Hadorn et al., 2008),

goes beyond distinct disciplinary concepts and theories (Klein, 2010),

incorporates academics and non-academics knowledge and experiences using usually participatory methods (Lang et al. 2012),

is critical and reflexive (Jahn & Keil, 2015).

As the most important characteristic of transdisciplinary research is the active involvement of the non-academic actors, Blackstock et al. (2007) describe participatory research as "participants collaborating to problem solve and produce new knowledge in an ongoing learning and reflective process". Such research approaches facilitate mutual learning processes among all actors involved, encouraging thus the co-creation of knowledge (Lang et al., 2012).

Focusing on agricultural research in the European Union (EU), sustainable management of natural resources, food security and economic viability of the farming sector are considered as important societal issues. In the policy context, the European Commission (EC) aims to address these major challenges faced by the agrifood system through the contribution of the European Innovation Partnership for Agricultural Productivity and Sustainability (EIP-AGRI), which has been established as a new way to foster innovation in agriculture and enhance the competitiveness and sustainability of European agriculture (EC, 2012). In this regard, it follows an interactive innovation approach which links science and practice, encouraging the co-creation of knowledge via meaningful collaborations between researchers and concerned actors, e.g. farmers, advisors, businesses, NGOs, etc. (EC, 2016). The Horizon 2020 research framework programme (H2020)[7] supports this interactive innovation model through the implementation of the Multi-Actor Approach (MAA) research projects in which various end-users and practitioners are truly engaged throughout the project's lifetime (EIP-AGRI, 2017). Furthermore, several calls of H2020 stimulate transdisciplinarity in projects which brings together knowledge from different disciplines and integrate it considering societal experiences as well (EC, 2017).

Nevertheless, participants' involvement and interaction in research processes may vary. Thus, Brandt et al. (2013) point out that one of the challenges transdisciplinary research has to address is the engagement of practitioners from outside academia. They acknowledge four different increasing levels of practitioners' involvement, from information through consultation and collaboration towards empowerment, in which practitioners have the power and control to influence decision making. Accordingly, the knowledge generated through the interaction between the various scientists and societal actors in transdisciplinary research can be differentiated into four levels, "one-way information" when information is transferred only by one side; "mutual one-way information" when information is transferred by both sides at the same time; "collaborative research" when shared new knowledge is generated through knowledge exchange; "joint decision-making" when scientists and actors interact also with policy and decision makers (Wiek, 2007). Based on the Arnstein's (1969) Ladder of Participation and OECD (2004) typology of public involvement, Blackstock et al. (2007) deem participatory research as the processes throughout which stakeholders have the capacity to shape what affects them and develop solutions (upper categories in the ladder, i.e. delegation and support).

Taking into account the benefits of genuine actors' engagement, the EU research project "UNderstanding and Improving the Sustainability of agro-ECOlogical farming systems in the EU" (UNISECO) uses transdisciplinary processes fostering collaboration work with various non-academic actors during the course of the project in order to better understand the socio-economic and policy factors that hinder or enhance the transition towards agro-ecological farming systems in EU. UNISECO aims to strengthen the sustainability of EU farming systems, through co-constructing practice-validated strategies and incentives for the promotion of improved agro-ecological approaches, as such approaches may contribute to sustainable agri-food system ensuring sufficient and safe food production as well as the provision of vital public goods (FAO, 2018).

A specific Work Package in UNISECO dedicated to multi-actor engagement aims mainly to develop and test new transdisciplinary methodological approaches in policy research and analysis as well as to interpret societal expectations using participatory processes with stakeholders and end users. The collaborative learning between science and stakeholders is facilitated through the Multi-Actor Platforms (MAPs) or in other words the pools of relevant actors who are engaged in the various scientific activities of UNISECO.

The establishment of a monitoring and evaluation framework that guide the steps for assessing the performance of MAPs and the efforts made through the participatory approaches for knowledge co-construction and co-learning are explored in this work-in-progress paper. The paper consists of the following: starting with a review of literature on evaluation of the

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[7] Horizon 2020 is the Framework Programme for Research and Innovation for 2014-2020 funded by the European Commission https://ec.europa.eu/programmes/horizon2020/en/what-horizon-2020

transdisciplinary and participatory approaches; the transdisciplinarity approach in UNISECO along with the selection of relevant evaluation criteria to project's objectives are then presented; the results of the first pilot application to a project activity associated with the MAP members at the EU level are provided. The paper concludes by identifying future steps of the framework in order to ensure that dialogue and collaborative learning within MAPs are promoted.

2. Transdisciplinarity in UNISECO

The ambition of the UNISECO project is to co-construct with stakeholders and end-users improved, practice validated strategies and incentives for the promotion of agro-ecological farming systems (AEFS) in the case studies in the 15 partner countries.

UNISECO employs a transdisciplinary research approach which is performed through three key mechanisms: 1) the consortium composition, 2) setting up networking and knowledge sharing platforms and 3) the inclusion of participatory methods in all project phases. In particular, the composition of the consortium includes researchers who come from different backgrounds and scientific disciplines (humanities, social and natural science) as well as partners from non-research organisations. The most fundamental element of the transdisciplinary character of the UNISECO project is the inclusion of individuals external to the consortium who are drawn from multiple non-academic organisations (such as farmers, advisors, processors, environmental stakeholders and policy makers). This ongoing involvement is performed through the MAPs, i.e. one EU level and 15 local (at each case study area) pools of key actors associated with AEFS. The aim of the MAPs is to open two-way exchange of ideas for co-learning and co-creation of knowledge through participatory processes in various intersection points throughout the project's duration.

Besides the MAPs, two other mechanisms facilitate knowledge exchange within UNISECO: 1) the Project Advisory Group (PAG), consisting of external experts who provide guidance and advice on the central scientific scope, and 2) the Stakeholder Reference Group (SRG) formed by representatives from case study MAPs expressing local stakeholder's views on overall project activities.

The UNISECO project attempts to ensure that through engagement processes, the real needs on the ground are met, as well as that the different types of knowledge are incorporated into all stages of research and dissemination. Subsequently, the multi-actor approach is driven by specific guidelines and criteria in order to increase project's impact and co-develop innovative practical solutions. Firstly, all project partners identify and select potential individuals for joining in the MAPs according to a set of predetermined criteria that assess them against their interest, availability, relevance, appropriateness, representativeness and willingness (Budniok et al., 2018). Furthermore, project partners are guided and advised on how to meaningfully interact with MAP members as well as how to design and carry out participatory activities that may support exchange of knowledge and experiences among the various actors (Irvine et al., 2019).

All the aforementioned illustrate the structures of UNISECO to facilitate engagement and collaborate with various actors, so that project results are co-generated and practically utilised by the relevant societal actors. For this reason, the transdisciplinary approach of the UNISECO project is completed with the monitoring and assessment of mechanisms and approaches used throughout the course of the project.

3. Monitoring and evaluation framework

3.1 Literature review

The overarching objective of the multi-actor engagement in UNISECO is to develop a monitoring and evaluation framework for assessing the project activities in which non project actors are involved. For this purpose, it was considered necessary to review the literature on evaluation of the transdisciplinary research and participatory approaches relevant to sustainability and socio-ecological systems in order to identify and select appropriate evaluation criteria and methods for measuring project activities which engage non project actors with respect to achieving their purposes and giving constructive feedback for improvement.

Although the transdisciplinary approach is advocated by funders as well as researchers, the literature doesn't provide guidance on how to design, implement and measure research that use transdisciplinary and participatory approaches (Blackstock et al., 2007; Lang et al., 2012; Holzer et al., 2018). Additionally, the evaluation of transdisciplinary research is considered complex (Klein, 2008), since it has to integrate knowledge from various disciplines, develop dynamic methodologies that are context and problem-specific and involve non-academic actors (Carew & Wickson, 2010). It is argued that these challenges have delayed the progress in developing widely approved criteria for judging the quality of transdisciplinary research and define when transdisciplinary research is successful (Jahn & Keil, 2015). Since the specific characteristics of the transdisciplinary research and how it is implemented determine the criteria for its evaluation, many papers first define transdisciplinary research (e.g. Jahn & Keil, 2015; Holzer et al., 2018; Bergman et al., 2005; Lang et al., 2012).

Based on the literature review, some scholars are interested in developing frameworks for evaluating transdisciplinary or participatory research (e.g. Blackstock et al., 2007; Hassenforder et al., 2016), while others deal with the quality of transdisciplinary research proposing guidelines and specific quality criteria (e.g. Lang et al., 2012; Bergman et al., 2005; Jahn & Keil, 2015).

Blackstock et al. (2005) have developed an elaborate framework that illustrates the significant characteristics of the evaluation concept. The framework emphasises that the timing, purpose and focus determine the different types of evaluations, providing a comprehensive list of suitable evaluation criteria compiled from literature in order to measure the research process, outcome and context. The evaluation methods (interviews, surveys, document analysis, media analysis, observation, field notes, cost benefit analysis, impact assessment) should be context-sensitive and their choice depends on the objectives and focus of the research project, but also on the timing, purpose and focus of the evaluation. The framework was applied to a post summative evaluation of a regional sustainability project in Australia, involving a broad spectrum of participants aiming to reflect on the outcome and the learning aspects.

In line with Blackstock et al. (2005), the study of Hassenforder et al. (2016) deals with the challenges faced, when selecting and implementing methods, in order to monitor and evaluate participatory processes in the field of environmental or natural resource management. It is argued that a plethora of qualitative and quantitative methods should be considered for use (baseline studies, stakeholder analysis, attendance lists, questionnaires, semi-structured interviews, participants' expectations before and after the workshops, participants' observations by the evaluators, etc.) in order to ensure a wide range of data collection and data triangulation. The authors develop a framework for the monitoring and evaluation of a participatory process in Uganda, suggesting how to combine methods that are mixed, qualitative and quantitative, static and adaptive, theory-based and participant-based, process and outcome-oriented.

Nevertheless, among evaluation methods, the written questionnaires and interview-based surveys seem that are commonly applied due to clarity, flexibility and easiness of their use (Holzer et al., 2018).

To fill the gaps in literature, Walter et al. (2007) focused only on the evaluation of the societal effects of transdisciplinary research projects, which are related to the knowledge and decision making capacity that stakeholders may gain through their involvement in the transdisciplinary process and their collaboration with the scientists. Authors proposed a model which was applied in an ex-post evaluation of a transdisciplinary project (two years after its completion) taking a quantitative statistical approach to test the relation between the three types of social effects, i.e. outputs, impacts and outcomes. The correlation between project's involvement and the social outcome of increased decision making capacity of stakeholders was found to be statistically significant and is especially mediated through the social impacts of the network building and the use of transformation knowledge.

The benefits of stakeholder participation in environmental decision-making are discussed in a comprehensive review paper by Reed (2008). It is claimed that the decisions made by stakeholders are influenced by their engagement process, highlighting thus practice principles and key criteria that may lead to effective stakeholder participation.

On the other hand, Lang et al. (2012) presented a set of design guidelines for transdisciplinary research in sustainability science, presenting a conceptual model of how an ideal–typical transdisciplinary research process can be planned and carried out. Based on the conceptual model, they distinguish three different phases in transdisciplinary research process: (A) recognition and structure of the problem as well as the composition of the research team that should develop a common understanding of the problem addressed, (B) joint creation of knowledge which is transferrable and solution-oriented through synergistic research work, and last, (C) implementation, review and adjustment of the project results taking into account their practical use for the society and science. For each of the three phases, they formulate a set of design principles for transdisciplinary research along with relevant guiding questions that could be subject to evaluation, providing thus support to the research team and practitioners for successful research. They put emphasis on the necessity for a continuous formative evaluation, i.e. evaluate the process of operating and progressing a project in a reflexive way providing useful information and ongoing feedback in order to revise and improve learning and research quality. In this concept, Bergman et al. (2005) developed a long list of specific and detailed evaluation criteria which are arranged according to the project timeline for assuring the quality and examining the success throughout the course of a project.

Additionally, the study by Jahn & Keil (2015) is concerned with the quality assurance of transdisciplinary research that deals with policy making for sustainable development. Since the quality of transdisciplinary research is dependent on the collaboration and shared learning between the scientists and non-scientific actors, transdisciplinary research processes should pay attention to the integration of knowledge, perspectives, needs and values of the different actors involved, i.e. researchers, program managers or donors, and policymakers.

In general, evaluation methods and criteria should be tailor-made to project's aims and context, as well as all individual objectives, expectations and interests. When evaluating transdisciplinary approaches, emphasis should be put on the various opportunities for knowledge creation and the involvement of the external actors in the research process, the conditions of building trust, collaboration and mutual understanding, as well as the practical applicability of the outcome.

3.2 Towards an evaluation framework

The findings from the literature review have been synthesised and adjusted to the UNISECO purposes in order to develop a monitoring and evaluation framework primarily aiming to assess the performance of the MAPs in promoting co-learning and capacity building of key stakeholders at EU and local levels. In addition, there is a need to evaluate the process per se on the one hand and reflect on project teams' performance during this process, on the other hand. Consequently, the framework focuses on the project activities in which MAPs are involved, aiming to assess the process and outcome of the various transdisciplinary and participatory activities carried out during the project. Thus, the overall objective is to conduct an ongoing evaluation that critically analyses and examines the quality of the activities and point to the positive and negative aspects of their implementation, so as to adjust and improve both the approach and the team's performance for the research activities to follow.

The monitoring and evaluation framework addressed the following aspects:

assess the effectiveness of the project activity in which the MAPs' members were involved by examining whether it succeeded to engage the participants and accomplish its intended objectives and outcomes;

check whether the method of engagement used was appropriate and successful, whether the phases of preparation and execution process of the research activity were well organised;

appraise the degree to which the activity promoted transdisciplinarity and increased mutual learning.

Consequently, the evaluation procedure attempts to answer the following key questions:

Did the research activity reach its target groups?

Did the MAP engagement meet its objectives and achieve the intended outcome?

What worked well and what constraints/difficulties occurred through planning and implementation processes?

Did it promote mutual learning among different participants and co-construct knowledge?

What were the lessons learnt, for the project team and participants involved?

What should be changed for future activities?

For the purposes of the project, relevant evaluation criteria drawn from the literature review are compiled and grouped into three sets applying to the different phases of the research activities: preparation, implementation, post-implementation. The criteria are mainly adapted from Blackstock et al. (2007), who present a detailed list of criteria used for the evaluation of participatory approaches (e.g. relevant papers focused on stakeholder participation are Rowe & Frewer, 2000; Richards et al, 2004; Grant & Curtis, 2004), and combined with similar criteria other scholars have proposed (Walter et al., 2007; Hassenforder et al., 2016; Holzer et al., 2018; Reed, 2008).

Concerning methods, a combination of qualitative and quantitative methods is used in order to ensure that information from multiple perspectives, i.e. project and non-project partners, is gathered. Methods include observation and reporting/debriefing sheet filled by project partners and feedback questionnaire requested from participants.

Given that the MAPs' members are continuously engaged in all project phases, the UNISECO team was cautious and avoided engaging external participants also in designing the evaluation process, particularly in the initial stages, i.e. for selecting evaluation criteria, as this activity would increase the risk of stakeholder fatigue.

3.3. Operationalisation of the evaluation framework

The evaluation criteria cover the steps of preparing and conducting the research activities in which the MAPs members have been involved as well as the MAP members' feedback on the effectiveness of the outcomes. The sets of evaluation criteria suggested to be applied to the UNISECO evaluation are summarised in the following table (Table 1).

Evaluation Criteria Set		
Operational	**Process**	**Outcome**
Participants' profile	Representativeness	Network building
Design of the process	Access to resources	Capacity building
Level of involvement	Group dynamics	

Table 4. Suggested evaluation criteria for the UNISECO project

3.3.1 Operational criteria set

A debriefing/reporting sheet to be completed by project partners was designed to provide quantitative and qualitative information about:

Participants' profile: number of stakeholders engaged in the activity, categorized by gender, age, professional background, geographic location, etc.

Design of the process: Description of the activity's preparation and participants' identification and selection establishing transparent and objective justification of who is involved in the research activity and how the activity was planned and executed.

Level of stakeholder involvement: The consistency and loyalty in participation for each MAP member, in case of multiple project activities.

3.3.2 Process criteria set

At the end of group project activities (i.e. focus groups, workshops), questionnaires are distributed, detailing the feedback and perceptions of participants involved about the activity process in relation to representativeness, access to resources and group dynamics.

Representativeness: When a participatory process takes place, it is crucial to ensure that representatives of the key stakeholder groups are involved in the activity and viewed as legitimate, so that diverse viewpoints, interests and values are considered.

Access to resources: Access to relevant and appropriate to the research context information allows participants to effectively participate in the research activity. In addition to adequate information, enough time for interaction should be given ensuring effective facilitation.

Group dynamics: Referring to participants' ability and opportunity to participate and influence the process, outcome and others, thus effectively collaborate and learn from their involvement in the research activities. Participants should follow the principles for involvement in the MAPs including aspects related to respect, sharing, listening, attention and teamwork.

3.3.3 Outcome criteria set

Questionnaires are completed by participants who are actively and continuously involved in group research activities (focus groups, workshops), providing their feedback on the effectiveness of their engagement and their satisfaction. Questions of this criteria set are usually relevant at the latter stages of the project, since they focus more on the influence of the overall project activities on participants' capacity.

Network building: Referring to size and strength of networks and relationships that improve professional opportunities. When existing social networks are strengthened, new ones and collaborations are developed as a result of the involvement in the project.

Capacity building: Referring to change in knowledge, skills, relationships, understanding, trust that enable participants to take part in future processes and projects. When participants experience some transformation in their knowledge, skills, viewpoint due to their involvement. When project results meet the needs of stakeholders and can be used by them in everyday context, leading to a sense of ownership of project results.

4. Pilot application of the monitoring and evaluation framework

The proposed monitoring and evaluation framework was first applied in the stakeholder workshop carried out in May 2019, in the framework of the 1st annual meeting of the UNISECO project in Helsinki, Finland. The specific workshop has served as a pilot in order to get feedback from non-project attendees testing the evaluation questionnaire for participants (work in progress). The evaluation questionnaire (see Appendix) is mainly divided into three parts, trying to elicit information from attendees on issues related to the access to resources, representativeness and group dynamics. The questionnaire comprises 16 questions asked in a five-point Likert scale format ranging from 'strongly disagree', to 'strongly agree', encouraging respondents to add their comments against each question so that further information is provided.

The workshop was mainly composed of three different sections having presentations, discussions in small groups and plenary sessions, aiming (a) to validate the typology for agro-ecological farming systems and the case study selection; (b) to review the modelling framework for assessing the sustainability of agro-ecological farming systems at territorial level; and (c) consult with the external actors the key themes for the first set of policy briefs.

Apart from the UNISECO consortium partners, 14 members of the different groups, PAG, EUMAP and SRG that complement the project team, attended the workshop. After the end of the workshop, evaluation questionnaires were sent by email to all external attendees.

5. Evaluation results

5.1 Profile of the respondents

Out of the 11 external stakeholders who completed the questionnaires, four were grouped as EUMAP members, four as PAG members and three as SRG members. The stakeholders included representatives of local and EU-level farming and producer organisations, environmental NGOs, ministries, EU-level networks commissioned by DG Agri as well as social and natural scientists covering different disciplines. Among them, there were six males and five females coming from across Europe, thus having a good balance concerning the gender and geographical distribution. In relation to the professional background, most of them identified themselves as researchers/professors in various faculties of agronomy and environmental science (six respondents), while all of them seem to be knowledgeable about sustainable agriculture.

5.2 Access to resources before the meeting

Attendees were asked to rate the level of agreement or disagreement with statements about the clarity, relevance and helpfulness of background information provided before the workshop (Figure 1). The majority of the respondents strongly agreed that when they were invited, they were informed about the objectives of the workshop in a clear way (7 respondents), while information was relevant to the issues raised during the workshop (6 respondents). Nevertheless, three respondents commented that they received the agenda just a few days before the meeting, thus they didn't have adequate time to prepare themselves. Moreover, although the information corresponded well with the workshop's agenda, some respondents found that it was not complete, as it didn't cover all issues raised at the meeting, while earlier involvement of some attendees helped them to become more familiar with project's issues.

5.3 Access to resources during the workshop

Almost all participants responded positively that the objectives of the meeting and their role were clearly explained to them at the beginning of the workshop (Figure1). Nevertheless, one SRG member expressed that their role during the workshop was not specified so one didn't know exactly what to do, "*to give opinions or be silent and learn*".

Concerning the workshop content, the outcome of the analysis suggests that it fulfilled the needs and interests of the majority of attendees (9 positive responses). Although two respondents remarked that the workshop topics were not close to their work, the respondents perceived that their contribution was useful.

Although there was a tight agenda and a large group of attendees, almost all of them responded that there was enough time allowed to express views and pose questions (9 positive responses). Nevertheless one EUMAP member felt that the workshop's duration should have been for half a day more, and one SRG member argues that it is more important "*to offer quality time and comfort*".

Finally, concerning the role of facilitators, nearly all respondents (10 out of 11) agreed that facilitators were active in ensuring a good flow of the discussion expressing positive comments about them.

5.4 Representation of interests and interest groups

Three of the respondents indicated that the representation of stakeholders was not ideal, while five of the respondents expressed that some groups of relevant stakeholders should have been also present at the workshop (Figure 1). Comments received focused on the absence of farmers' representation as well as of any policymaker and on the other hand on the dominance of some male researchers and academics, thus there was overrepresentation of opinions and interests. Moreover it is stressed that people feel more comfortable to express themselves in small group discussions rather than plenary sessions.

5.5 Group dynamics during the workshop

With very few exceptions, all respondents fully agreed that they could trust the team members, they had been always given opportunities to express their viewpoints and felt comfortable in sharing them, while everybody was open to constructive criticism (Figure 1). Nevertheless, it should be stressed that one SRG member mentioned that the lack of expertise in technical issues inhibit active participation.

Figure 1 depicts the answers given by the 11 respondents to the 16 Likert scale questions (Q1-Q16).

Short description of the 16 Likert scale questions		Distribution of response (N=11)
Before the meeting	Q1. clear meeting's objectives	4 7
	Q2. relevant information to the issues raised	2 1 2 6
	Q3. helpful information provided	1 4 5
Based on the meeting's objectives	Q4. representation of all interests	1 2 2 6
	Q5. absence of some groups, associations, persons	3 3 2 1 2
	Q6. fair chance for all participants	1 3 7
	Q7. overrepresentation of opinions, interests	6 1 1 2 1
During the meeting	Q8. clear understanding of the process	1 4 6
	Q9. content relevant to needs and interests	2 4 5
	Q10. enough time	2 4 5
	Q11. active facilitator (competent)	1 1 9
	Q12. trust the team members	1 10
	Q13. comfortable environment	1 1 9
	Q14. opportunity to speak	1 10
	Q15. open to constructive criticism	1 2 8
	Q16. attempt to manipulate	8 3

strongly disagree	disagree	neither disagree nor	agree	strongl

Figure 4. An overview of the distribution of the respondents' answers[8].

5.6 Contribution of the MAA to the workshop objectives

The specific objectives of the workshop were to discuss the coverage of the UNISECO case studies of agro-ecological transitions and to demonstrate and consult on the assessment tools at farm and territorial levels.

Detailed demonstrations of the different assessment tools took place in small groups during the workshop. Participants were actively discussing the functionality and strengths and weaknesses of the different tools, jointly identified key aspects that are covered by the tool as well as suggested additional aspects (e.g. in relation to quality of life and well-being of farmers) that could be assessed. Replies to the questions 8 – 15 covering aspects of active involvement, trust, listening and learning indicate that some level of co-learning and co-construction was

[8] Numbers in the cells indicate the number of respondents, whereas the different colours represents the range from strongly disagree to strongly agree.

achieved (Figure 1). This is supported by individual feedback of participants (e.g. "*There was clearly on-going co-construction of approaches in several areas and this seemed very welcomed*"; PAG member). However, the feedback from the participants also suggests that the involvement of missing types of key actors and more time for preparation would have further enhanced successful co-learning and co-construction during the workshop.

6. Conclusions

Although the H2020 MAA projects are highly welcome and increasingly funded by the EC, literature doesn't provide adequate guidance on how to design, implement and measure projects that use transdisciplinary and participatory approaches. Based on a literature search, although not exhaustive, a set of methods and criteria can be derived in order to develop a monitoring and evaluation framework that will aim to assess activities in which various stakeholders are involved. For this purpose, relevant evaluation criteria based on the literature review were compiled and grouped into three sets that describe the different phases of the research activities: preparation, implementation, post-implementation. This work-in-progress paper presented some initial results based on the pilot evaluation conducted through a participants' questionnaire which was tested in the framework of the 1st stakeholder workshop of the UNISECO project.

Taking into account the evaluation feedback, the following key points seem to be essential in order to actively involve non project partners in a two way knowledge transfer process:

External actors need to be aware of their role during the meetings, having beforehand background information in order to be well prepared.

Apart from academics and researchers, other interest groups, especially farmers' representatives should be engaged in the meetings.

The presentations and discussions during the meetings should be adjusted according to the audience's level of expertise and knowledge.

Plenary sessions and small group discussions seem to be a preferred combination of methods for the workshops, trying to ensure a balance of conditions in terms of gender, profession and expertise.

Overall, the experience confirms that a well prepared and animated participatory workshop approach leads to better workshop results and lessons learnt have been derived for future project workshops.

The questionnaire will be further tested and the proposed monitoring and evaluation framework should be seen as a learning exercise. The feedback from the workshops participants' along with experience gained from designing and implementing participatory activities will help the project team to revise and make improvements.

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9. Annex: Participants' Questionnaire

Activity/Task:

Code: [……………]

Gender: Female Male

Professional background:

Origin:

Please indicate the level of agreement or disagreement with the following statements, we would really appreciate a brief explanatory text with your evaluation.

	Strongly disagree	Disagree	Neither agree nor	Agree	Strongly agree	Comments
Based on the information that was given when I was invited…						
1. The objective(s) of the meeting was/were clear to me.	①	②	③	④	⑤	
2. The information was relevant to the issues raised during the	①	②	③	④	⑤	
3. The information helped me understand the issues at stake	①	②	③	④	⑤	
Considering that the [theme, objectives, ….] of the meeting was/were [……..]						
4. I think that all interests have been represented in today's	①	②	③	④	⑤	
5. I think that there were groups, associations, persons	①	②	③	④	⑤	
6. I think that all participants had a fair chance to express their	①	②	③	④	⑤	
7. I think that there was overrepresentation of opinions, interests	①	②	③	④	⑤	
During the meeting						
8. When today's meeting started, the objectives of the	①	②	③	④	⑤	
9. The content of the meeting was relevant and consistent to my	①	②	③	④	⑤	
10. There was enough time allowed to express views and pose	①	②	③	④	⑤	
11. The facilitator was active in ensuring a good flow of the	①	②	③	④	⑤	

12. I felt that I could trust the team members with whom I	①	②	③	④	⑤
13. I felt comfortable in sharing my viewpoint.	①	②	③	④	⑤
14. I had always the opportunity to express my point of view	①	②	③	④	⑤
15. I felt that all participants were open to constructive	①	②	③	④	⑤
16. I felt being manipulated by powerful participants	①	②	③	④	⑤

Other comments, issues you would like to mention

IMPROVING FARMING ADVISORY SERVICES TO STIMULATE DEVELOPMENT OF SUSTAINABLE AGRICULTURE

Boelie Elzen[a], Jaroslav Pražan[b], Lee-Ann Sutherland[c], Livia Madureira[d], Cristina Micheloni[e], Pierre Labarthe[f]

[a] Wageningen Research (Netherlands)
[b] Ekotoxa (Czech Republic)
[c] James Hutton Institute (Scotland)
[d] UTAD (Portugal)
[e] Vinidea (Italy)
[f] INRA (France)

Abstract

European agriculture faces several sustainability issues that require various types of innovations (technological and social). Farming advice and farming advisors play in important role in this innovation process. This paper is based on the ongoing EU funded AgriLink project that develops new insights in how farming advisory systems (FAS) can operate to assist farmers in addressing the new challenges that they are facing. This also raises new challenges for advisory services that target the farm level, including the governance of advisory services at regional and national levels, the overall coordination of the system and the types of innovation that are at stake.

The research is based on an analytical framework that integrates concepts that operate at different levels, including the farm level, the wider agricultural system (the innovation environment), and policy and institutional environments. For each of these levels, the project analyses its role in the innovation process with a specific focus on sustainability issues in a set of eight domains of agriculture ('innovation areas'). An integrated assessment of all these factors is facilitated by the use of several frameworks, including the triggering change model, the multilevel perspective (MLP), and insights from organisational learning. The analysis is based on case studies from thirteen countries across Europe which allows the analysis at each of the indicated levels for various agricultural domains in different innovation contexts.

Introduction

Farming advisory systems

European agriculture faces several sustainability issues that require various types of innovations (technological and social). The development and further uptake of innovations takes place in a situation of increasing plurality within Agricultural Knowledge and Innovation Systems (AKIS) and Farm Advisory Systems (FAS). This raises new challenges for advisory services that target the farm level, including the governance of advisory services at regional and national levels, the overall coordination of the system and the types of innovation that are at stake.

This paper develops new insights in how FAS can operate in the changing AKIS to assist farmers in addressing the new challenges that they are facing. The paper is based on research within the EU-funded AgriLink project that runs from June 2017 to May 2021. It presents the initial findings of the integrated assessment of the results of various work packages that will be further developed in the coming years and also describes methods to increase understanding of the role of the FAS in the agricultural innovation processes.

The sustainability challenge

Increasing the sustainability of agricultural systems is an important, longstanding societal and policy objective (Pretty 2002). The Brundtland Report (World Commission on Environment and Development, 1987), 'Our Common Future', defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". The pursuit of sustainable agriculture is embedded in European agricultural policies (see Council Regulation (EC) No 1257/1999, Marsden, 2003, Wilson, 2007). However, the definition of sustainable agriculture is highly contested (Robinson 2008).

Sustainability is widely conceptualised as comprising three facets: environmental, economic and social (Velten et al. 2015, Kuhlman and Farrington 2010). Early work on sustainable agriculture emphasised environmental sustainability, particularly the benefits of organic farming and low input agriculture. The Commission of the European Communities' (1999) communication "Directions towards sustainable agriculture" has a strong focus on environmental sustainability, suggesting that sustainability is about balancing the use of natural resources for long-term agricultural production with the protection of the environmental and cultural heritage in line with society's values.

In AgriLink, we use the three-fold definition of sustainability. For agricultural practices to be sustainable, they must be economically viable, environmentally beneficial, and yield appreciable benefits to society (e.g. local employment, access to common pool resources), while not compromising the potential of future generations to meet their own needs. This 'triple bottom line' model of including environmental, economic and social aspects of sustainability has been widely used in the sustainable agriculture literature (e.g. Rasul and Thapa 2004, Van Calker et al. 2005) and provides an imperfect but practical option for conceptualising sustainability.

The AgriLink Approach

Research questions and key concepts

In the integrated assessment of the AgriLink project results we seek to answer the following three research questions:

What is the contribution of advisory services to farmers' decision-making regarding innovation to make farming more sustainable?

Can new forms of co-production of services (interactive innovation, Living Labs) contribute to better linking actors within a regional FAS with both farmers' needs and research and innovation of the advice provision itself?

How can transformations of the advisory system contribute to sustainable transitions of European agricultures?

The answer to the third question should lead to the identification of opportunities to design a more effective FAS which supports the uptake of innovations for agricultural sustainability. This last question builds on the answers and some particular findings related to the two first questions.

Because the project is not yet finalised, these questions cannot yet be answered in full. Therefore, the paper presents preliminary results, along with the approach to finalise the synthesis of the project findings.

AgriLink uses several concepts for which different definitions are used. These are first of all AKIS (Agricultural Knowledge and Innovations System) and FAS (Farm Advisory System). To assess the

FAS role in innovation process it was necessary to adopt particular definitions in order to distinguish FAS actors from the other AKIS actors.

The current usage of the term AKIS (where "I" is short for Innovation) more accurately represents the literature on AIS (Agricultural Innovation Systems), a concept which emphasises a broader network of organisations and the focus on new products, processes and forms of innovation (Birner et al. 2009). In AgriLink we will define AKIS simply as: "the collection of agricultural information providers, the flows of information between them, and the institutions regulating these relations"

Based on the definition initially presented by Birner et al. (2009) we define FAS as part of AKIS: "Agricultural advisory services are the entire set of organizations that will enable the farmers to co-produce farm-level solutions by establishing service relationships with advisors so as to produce knowledge and enhance skills" (Labarthe et al. 2013, 10). Based on Birner et al. (2009) we recognise organizations providing independent professional advice as FAS: Private/public/semi-Public advisory organisation, Advisors of farming organisations, individual/independent advisors, NGOs providing advice.

The FAS plays a key role in the knowledge and innovation transfer within a (national or regional) AKIS, alongside other sources of information (e.g. universities, input suppliers) as it is illustrated in the example Figure 1. FAS frequently plays an intermediate role between sources of knowledge (e.g. universities, research institutes), and usually also provides advice on public goods (in contrast to input providers). As a matter of distinction, we recognise FAS as organisations/individuals for whom providing advice defines their major role (e.g. advisory organisations, individual advisors) to distinguish them from actors for whom providing advice comes secondary (e.g. universities, input suppliers).

The figure below pictures the Danish AKIS as an example. Within this image, the FAS is represented by three entities, i.e. the Knowledge Centre for Agriculture, Local advisory centres (DAAS centres) and Private advisory companies.

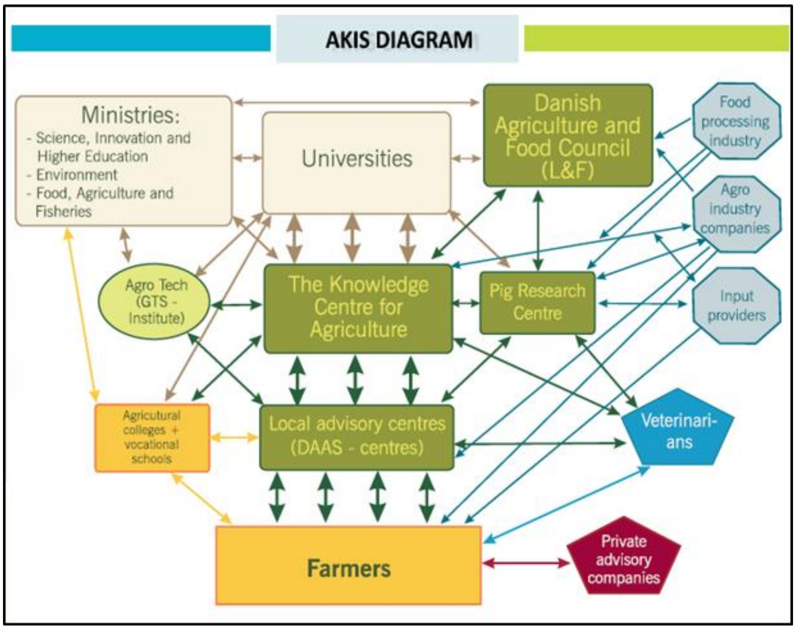

Figure 1: Example of AKIS Diagram from PROAKIS - Denmark case (Source: http://www.proakis.eu/inventory)

Methodology

Answering the first research question above builds on findings from a quantitative and qualitative survey at the farm level, the regional FAS level and a FAS governance assessment, also including a qualitative survey. The surveys were carried out in the form of one-to-one interviews.

Answering the second question is based on results from collaborative actions (in the form of Living Labs) that addressed several innovation types (described below), together with insights from farm level surveys (collecting evidence on types of innovation requiring specific types of advisors' assistance). Findings on FAS governance provides evidence on the extent to which these types of activity (Living Labs) are supported directly or by back-office activities (e.g. training of advisers). The Living Labs approach has been used as an advisory tool to explore and facilitate collective actions by actors, for instance in the case of social innovation. In AgriLink, the approach is used to design new advisory tools (e.g. in Netherlands to facilitate farmers' learning about how to reduce nutrients loss in arable farming). The project also analysis the conditions under which Living Labs can be a useful and effective tool for advice provision or for advisory tools design.

The answers to the research questions are intended to help design improvements to the existing FAS. Preliminary answers will be validated with agricultural stakeholders by exploring how such an improved FAS might actually stimulate the future development of a more sustainable agriculture in various EU regions. For this a so-called "Socio-Technical Scenario" (STSc) method will be used, which takes into account the potential barriers and drivers that play a role in shaping the future.

In AgriLink, we address agricultural sustainability by focusing on a set of innovation areas that combine (positively or negatively, with synergies or trade-offs) different dimensions of sustainable development (see Table 1 below). The innovation areas were chosen to represent the challenges identified in the Strategic Approach to EU Agricultural Research & Innovation (EC, 2016a). Each innovation area illustrates the difficulties of combining different dimensions of sustainable development, and the need to combine knowledge from different sources and of different types.

Table 1 – Innovations and case studies geographical distribution

Type of innovation	Innovations	Countries with case studies
Technological – IT (Information technologies)	Autonomous vehicles, robots, drones, intelligent sensors; Precision Farming	Czech Republic; France; Norway, Poland; Portugal; United Kingdom
Process – Integrated ecological farming	Biological Pest Control	Greece; Latvia; Netherlands; Portugal; Spain
	Soil Improving cropping systems	Czech Republic; Italy; Netherlands;
Marketing and organisational	Retro-innovation	Romania; Spain
	Introducing new crops	France; Greece (two cases)
	Direct marketing	Italy; Latvia; Portugal; Romania; Spain

	Developing new activities	Belgium; Poland
Social – Collaborative arrangements	Natural resources common management	Italy; Norway; Poland; United Kingdom
	Labour Innovative arrangements	Belgium; France

Concerning the adoption of innovations, Smith et al. (2010) argue that innovation studies broadened from a focus on promoting cleaner technologies in the 1980s to system-level changes in production and consumption. As such, innovation studies expanded from a technology focus, to current definitions which include methods, concepts and social aspects. Smith et al. (2010) also identify a broadening of understanding of how innovations emerge: early work emphasised economic price signals, whereas more recent work utilises innovation systems perspectives. Systems perspectives emphasise co-development of innovations, involving multi-actor processes and partnerships. Learning and change are shared and responsive to contexts (Klerkx et al. 2012). The iterative processes of innovation development and mainstreaming are developed particularly within the multilevel perspective (MLP; Geels 2005).

An innovation which does not have the potential improve either the economic, social or environmental condition of the farm is unlikely to be taken up. In many cases, however, there will be advantages in one area and disadvantages in another, i.e. trade-offs in what innovations achieve (Nelson and Nelson 2002, Tuomi 2002). Furthermore, some innovations will improve one aspect of sustainability at a cost of another. These trade-offs lead to variable adoption rates.

To acknowledge these aspects of innovation, AgriLink has adopted the following 'rules' as a point of departure:

AgriLink does not restrict the definition of innovation to technological innovation, but integrates process, marketing and social or organisational innovations;

AgriLink studies innovation areas where the contribution of innovation to sustainability is a matter of debate, hence there is a specific role for advice to play in that respect;

AgriLink explores innovation at different scales, and includes farmers who did not adopt an innovation that was analysed;

AgriLink not only analyses innovation but also aims to promote participatory methods for innovation within and through services, through six Living Labs.

Following classical taxonomies of innovation (OECD 1992), empirical research in AgriLink address four types of sustainable innovations: technological, processes and farming practices, marketing, and social and organisational. To acknowledge further variety, AgriLink assesses the role of advice in eight specific 'innovation areas' within these four general types (cf. table 1 above). These innovation areas were chosen to represent the challenges identified in the Strategic Approach to EU Agricultural Research & Innovation.

In AgriLink we will utilise both infrastructural and process approaches. Process approaches emphasise the interactive development of technology, practices, markets and institutions. An infrastructural approach identifies the actors and associated rules (including regulations) of AKIS; it is important to understanding the structure and functioning of the regional farm advisory services (R-FAS), and how they are influenced by the EU farm advisory regulations. The process approach emphasises the interactive development of technologies, practices and institutions which is important to understand on-farm innovation and microAKIS. Taking both perspectives is particularly useful within a multilevel perspective, and will be applied in different work packages.

Concepts used in AgriLink

AgriLink distinguishes three types of farmers, i.e. those who have, have not or have ceased adoption of a particular innovation. To understand the innovation process at the farm level the data collection had several foci:

To identify the sources of the information and support farmers drew on in deciding to (or not to) implement a particular innovation (i.e. the structure of their microAKIS).

To analyse the processes in which innovation decisions are embedded (e.g. informal networks, decision-making approaches, sequences of events).

To analyse the farm-level constraints and opportunities for engaging with innovations. These include the geographical features of the farm (e.g. land capability), the technological preparedness (e.g. ICT access) and the history of farm-level engagement with advisory services of various forms.

To analyse the innovation process at the farm level the concept of microAKIS was adopted which is based on Sutherland et al.'s (2012) conceptualisation of the 'triggering change model' (see figure 2 below).

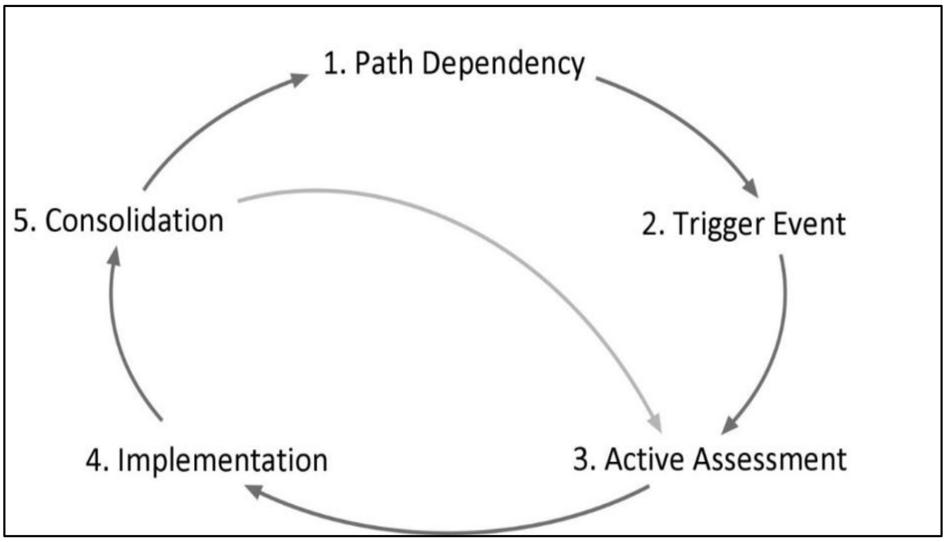

Figure 2: The Triggering Change Model (Sutherland et al. 2012, p. 144).

This model draws on social psychology (particularly the Elaboration Likelihood Model, Petty and Carpaccio 1986) to identify a sequence of events through which innovations come to be integrated into farming practices. The elaboration likelihood model argues that people do not attend to new information and opportunities in the same depth all of the time; only in particularly important situations do they process in the depth which is required to make a major change on farm. Farmers and their businesses are typically 'locked in' to their current trajectories. Making a change in farming practice therefore usually involves some form of trigger, which can range from a series of financial set-backs to the opportunity to integrate a successor into the business. These triggers lead to a period of active assessment or 'reflexivity' about opportunities and the overall farming trajectory. Once a viable option is identified, farmers may implement it. Subsequently, it takes time for the innovation to consolidate into the 'new normal' for the farm and become part of the status quo. Unsuccessful innovations trigger a return to active assessment. In AgriLink surveys were conducted on how this worked in concrete cases, yielding over 1000 responses.

Next to micro-level innovation adoption (or not), AgriLink evaluates the EU-FAS at the macro level, using a combination of structural and process approaches to assess how specific policies and governance approaches influence the structures and processes of advisory services 'on the ground' in the case study countries. EU-FAS is represented by a regulation by the European Commission on farming advice that is intended to guide member states on how to organise the advisory system in their country.

AgriLink also aims to increase understanding of the role and way of development of advisory support services by running of six 'Living Laboratories', where scientists, advisors and farmers work together to develop and explore new advisory techniques, in response to specific farming or farming related issues that could trigger innovation (e.g. shared marketing). This approach focuses on the processes of knowledge exchange, creation of links between advisors and farmers and conditions under which such an approach could be effective.

Different types of innovation require usually different advisory methods. Collaborative innovations where different actors have a stake and should be involved require facilitation of the process under group dynamics (Birner et. all 2009, Faure et al. 2016). This is also needed in some cases of advice on conflict resolution and substantial changes in farming systems (Faure et. al 2016). At the same time development of new advisory methods also requires in many cases close collaboration of several actors to address complexity of the issue and different interests of those with stakes in the relevant innovation process. Such activities build on existing social capital while also contributing to processes of building the social capital in AKIS and hence contribute to the creation of links between different AKIS actors. This requires the use of a group work format with facilitation provided, which is carried out using various methods and concepts. These include, for example: facilitation (Spencer 1996), design theory (Simon 1988) and systems thinking (Checkland 1999, Ostrom, Cox 2010).

To reflect the need for close collaboration of actors on new advisory tools or to assist farmers in their effort in collaboration, the Living Lab format was used within AgriLink (based on Design thinking theory, Simon 1988). The Living Lab design and run was inspired by system thinking (Checkland 1999). One aim was to test this particular approach in different innovation areas and different (national) contexts to provide lessons for different actors. Another aim was to identify and explain the role of such activities in the innovation process including creation of new links between AKIS actors.

A final element of the AgriLink approach is the use of so-called "transition scenarios". These will be developed in stakeholder workshops to explore which FAS changes and under which conditions could help to stimulate sustainable farming development in each partner country. All previous project findings will feed into these transition scenario exercises which will address both infrastructural and process approaches: the desired infrastructure under particular scenarios, and the processes associated with reaching these infrastructures, and characterising the associated AKIS.

Case studies

A set of case studies was carried out in 13 EU countries to collect data on how farming advice played out at the farm-level. This was analysed by studying the uptake of different types of innovations from 2-3 regions within each country. Farmers' micro-AKISs were surveyed and analysed for 32 case studies. These case studies focussed on farmers' decision-making processes regarding the adoption of specific innovations to understand the role that advisors, in particular each regional Farming Advisory System (R-FAS), played in these processes. Table 1 gives an overview of the innovations studied and the countries in which the cases were carried out.

The innovations were selected to cover the main innovation areas in agriculture and include innovations that were already partly disseminated in the chosen regions. This allowed surveying farmers that made different choices on adopting the innovation, distinguishing between adopters, non-adopters and droppers (farmers that started to use an innovation but dropped it after some time).

Data on farmers' micro-AKIS were collected by adopting a mixed-method approach, combining desk research with surveying of farmers, advisors and key actors from the AKIS underpinning the innovation. The structure of the survey followed the triggering change model (TCM) described above. Hence, data concerning farmers' micro-AKIS were gathered for the different TCM stages, to answer questions on who, how and why supported farmers in the different stages, *i.e.* raising awareness, assessment and implementation of the innovation.

Over one thousand interviews were conducted with farmers, corresponding to an average of 35 interviews per case. Additional interviews were carried out with nearly two hundred advisors and other actors with an important role in the AKIS related to the innovation area in each case. For these, the number of interviews per case varied considerably due to variation in the number of relevant advisory providers in different cases.

Initial results

General findings

A first result is that we found a large variation in the number of advisors that played a role in the various cases. In some cases, a farmer received advise from various sides in all stages of the process whereas in other cases hardly any advice was obtained. In addition, for most of the case studies, we observed that the advisor's diversity doesn't vary significantly during the different stages in the TCM, although in many cases advisors are absent or have a limited role in the innovation uptake stage.

The composition of a farmer's micro-AKIS, i.e. all sources of information and advice that a farmer uses, depends on the type of innovation although this tends to be strongly affected by the main features of the corresponding R-FAS. More specifically, the privatisation of the R-FAS across Europe, with the disappearance of the public advisory services in most of the countries resulted in a fragmented advisory landscape which is reflected in the micro-AKIS diversity across innovations and EU regions.

Results related to innovation areas

In this section we provide an overview of farmers' micro-AKIS by innovation type across different European regions. This will show a decreasing role of R-FAS and conventional advisory services when moving from 'off the shelf' technological innovations towards novel and complex social and organisational ones.

We analysed a diverse set of IT cases as shown in Table 1. The farm structure, more specifically farm size, appeared to be a determinant factor for the uptake of such innovations. These digital innovations appear to be more suitable for large farms, which are often led by farm managers or highly educated farmers. This could partly explain why there are only a limited number of actors involved in the micro-AKIS, given that 'self-learning' processes often occur and that in some cases there is a role for pioneering farmers at the regional level. An additional explanation is that specific technologies are usually owned by technology providers and that developments in this sector occur so rapidly that the R-FAS in most cases cannot keep up. Therefore, the private companies selling the technology play a key role in all countries, while they play a leading role in CZ, PL and UK cases on precision farming technologies. Poland is relatively exceptional given that regional public advisory services are still existent and appear to complement the role of the private suppliers by delivering independent advice to farms of different sizes. In three other countries, with case studies involving specific smart technologies like drones (France), milking robots (Norway), and moisture probes (Portugal), the farmer-based organisations (FBO) were more prominent as advisors, although this was more limited in the French case (being active only in the awareness stage). In Norway, the FBO worked side-by-side with cooperatives advising farmers on software and with private suppliers involved in development and assistance with the equipment (the robots). This is similar to the Portuguese case, although the probe manufacturers not only play a residual advisory role in this case. The Norwegian and Portuguese cases show that conventional advisors, the cooperatives in both cases, can play a relevant role by developing back-office activities enabling them to be involved in the development of the technology, esp. software. Thus, cooperatives can acquire knowledge that they need to use in the front-office to advice the farmers.

Process innovation focused on methods and /or techniques for biologic pest control (BPC) and soil improvement cropping systems (SICS). These innovations and the respective farm structures varied considerable across case studies which limits possibilities for cross-comparison. Due to this diversity, it is not surprising that farmers' micro-AKISes tend to vary substantially across innovations and countries. A general feature of these cases is that they show a large degree of self- and peer-to-peer learning processes. The relevance of researchers, directly or indirectly present in the farmers micro-AKIS is another shared feature across most of the case studies involving BPC or SICS. These innovations build on scientific knowledge which explains why researchers tend to be involved as direct and /or indirect advice suppliers. Formal provision of advice occurred in the Czech Republic (demonstration farms), in the Spanish region of Navarra, and in Greece by establishing partnerships between research institutes and local cooperatives. Informal arrangements were found in Italy (SICS), the Netherlands (SICS), and Portugal (BPC). In these cases, researchers collaborate with independent advisors and pioneering farmers (IT, NL) or with a farmer associations and pioneering farmers (PT). All cases show an important role for public policies funding collaborative projects and/or research and demonstration activities, including recently established operational groups.

The role of R-FAS in advice provision in the cases of BPC and SICS tends to be secondary, with the exception of Navarra and Latvia, were public extension still plays a role and collaborates with the research sector. In other cases, innovative advisory organisations (Portugal) or collaborative arrangements between research and advisory sectors (Greece and Netherlands) resulted in a successful uptake of innovations. In general, farming structures don´t play a significant role in limiting access to innovation, although the farmer's business models and their perception of the costs and benefits of an innovation appear to be decisive for non-adoption. In addition, in some of the case studies (e.g. IT, PT, LV) small-scale adopters tend to depend only on informal peer-to-peer advice.

The marketing and organisational innovations analysed by AgriLink involved a range of innovations and a large number of countries with diverse advisory landscapes. A generally observed feature is the decreasing role played by conventional advisory services. In relation to these innovations, in particular in the cases of direct marketing and retro-innovation, the farmers' micro-AKIS tends to be quite small and consists mostly of informal peer-to-peer advisory networks. In some cases there is involvement from non-conventional advisory actors, such as NGOs and the LAGs (local action groups) related to rural development policies supported by the regional RDP (Rural Development Programme). However, as shown by the Portuguese case, these advisors experienced difficulties to go beyond the awareness raising stage and appeared to be too dependent on dedicated project public funding to be able to support the actual uptake of collective direct marketing schemes. In other cases (Italy), successful new organisations (FBO NGOs) emerged along with these innovations and ensured the support to collectively involved farmers during the different TCM stages. The emergence of new types of advisors supporting marketing and organisational innovations and experiences from AgriLink Living Labs suggest that there is decreasing role of traditional advisory services (and an increasing role of new actors like NGOs) and, in general, insufficient supply of such services.

The uptake of various types of innovation, such as the 'pocket digesters' in Belgium, has failed due to the absence of an independent advisory service. In this case a very high rate of droppers was found due to lack of advice on the operation and maintenance of the equipment. The bankruptcy of the private supplier of the equipment left farmers in a problematic financial situation due to buying expensive equipment, following the advice of the seller. As a contrast, the introduction of similar activities (comprising a diversity of options for renewable energy production) in Poland was successful, partly related to the existence of local independent public advisory services.

The introduction of new crops is another rapidly spreading innovation across Europe. The micro-AKISes related to this innovation in the selected case studies showed an important role for the FBO, notably the local cooperatives involved in up- and down-downstream sectors. In these cases, peer-to-peer advice appears to be a relevant source of information in farmers' micro-AKIS, in particular in the Greek cases. In these cases (introducing stevia and avocado), researchers also appeared to play a significant role as advisors. This seems to be an innovation demanding an advisory system reflecting the value chain, triggering a farmers' demand for both technical and commercial advice.

The case studies on the uptake of social innovation showed the absence of traditional advisory services, with the exception of Poland, where local public advisory services played an important role. This is probably due to the trust that farmers have in these local advisors. Social innovation builds on collaboration and thus entails trust and motivation for participatory action. The importance of peer-to-peer advice along with the key role played by specific individuals, such as leading facilitators from NGOs, tend to shape the farmers micro-AKIS related to the collaborative arrangements for the natural resources common management.

EU and national advisory regimes

The first step in the analysis of national advisory regimes consists of exploring whether the recent EU regulation about farm advice actually had an impact on advisory regimes. Indeed, there has been an attempt by the European Commission (EC) to enforce a convergent guidance on advisory services in Member States (MS) through its regulation on Farm Advisory Systems. Since 2008, MS are compelled to set up such systems, aiming to guarantee that all European farmers can benefit from services to access information and knowledge to fulfil the EC's requirements about Good Agricultural and Environmental Conditions, or standards on the use of inputs (nitrates, pesticides), on health or on biodiversity issues.

Our preliminary results from desk research and interviews indicate that the European regulations had very limited impact on the national advisory regimes. There seem to be two potential explanations for this. The first applies to countries like France and the Netherlands, where farm advisory regimes are characterised by very strong institutions that define the identities of suppliers and frame the funding and attributes of services. In such contexts, national policy makers took the option to implement the EU regulation in its minimal scope, implying it had a very restricted impact on the system. The second applies to countries where the difficulties in the implementation of the EU-FAS regulation seem to result from a crisis of national advisory regimes, for instance in Greece or Romania. Such crises may be related to radical shifts in the balance of power between public and private actors in a context of sharp privatisation of advisory services. But it can also be an expression of a more global complexification of agricultural and rural polices with multiple layers (local, regional, national) and more and more complex policy instruments. As a results, the monitoring of policies impacting farm advice (for instance in terms of beneficiaries of services) is clearly lacking in many EU countries. In some countries (e.g. Czech Republic), the EU-FAS did have a noticeable impact and stimulated the development of the basic FAS institutions that did not exist before 1990 and that had started to evolve slowly since the EU accession.

At this stage of the project these results serve as an important context for understanding the FAS role in the dynamics of innovation processes. In later stages the results will be used as an important factor in explanation of the whole innovation process.

Innovation in FAS and design of new FAS tools

Our preliminary results indicate that there are several shortcomings in regional advisory systems to effectively support farmers in the uptake of sustainable innovations. Hence, there is a need for innovations in the FAS as well, in the form of new advisory methods and tools. In AgriLink we explore the design of such new tools and assess their usefulness in interaction with various stakeholders using the 'Living Labs' method, i.e. a workshop format with real-life actors exploring conditions and effects of changes relevant to them.[9]

The FAS governance analysis and whole innovation process studied at the project level assessed rules and support of building such capacities in FAS. The analysis of the micro-AKIS level revealed a need for innovation of the FAS itself, especially for particular types of innovation (e.g. collective actions). For example, a collective action undertaken by farmers in Scotland to agree on the collective application of an agri-environmental measure clearly showed a need for specific advice provision. The first results of the policy analysis (e.g. assessment of support of back office, training provision provided in project partner countries) show a lack of policies supporting such methods of advice, as well as lack of collaborative means to develop new advisory tools in some countries despite the need for such services (AgriLink results are supported also by personal experience in policy design in the Czech Republic). The preliminary results show that the provision of collaborative efforts facilitation in AKIS may be limited by several factors, for example when actors have too different interests (Norwegian Living Lab) or are acting under strong competition (Dutch Living Labs). This is in line with results from previous collective action studies (Ostrom 1990). Lack of policies supporting such advisory methods is associated to lack of AKIS coordination (e.g. study of Czech AKIS governance).

Conclusion

The AgriLink project follows a multi-method and multi-level approach to analyse the working of farming advisory systems in Europe. The analysis of micro-AKIS at the farm level is based on a wide set of case studies in various European countries. Desk research, combined with interviews, have been used to analyse national or regional advisory regimes, as well as the impact on these from EU policies. All of these levels clearly influence one another. A Living Lab method is used to explore the usefulness of new advisory tools in a subset of countries, seeking to address some of the challenges that emerge from the case study analysis. In the remaining part of the project, scenario methods will be used to explore possible and required future changes of the R-FAS in all of AgriLink's partner countries.

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[9] The use of Living Labs in AgriLink is elaborated in another paper for this conference by Potters et al.

The results presented here are only preliminary as, at the time of writing (fall 2019) the project still had 20 months to go. However, these results already indicate that the analysis of the different levels can be fruitfully combined to render suggestions to improve the farming advice system and test these in Living Labs. For example, insights in the gaps in advice provision in each step of the triggering change cycle (and their reasons), indicate where it would be useful to increase advisory competences, e.g. changes in governance and coordination. These can be translated into new policies to provide relevant training for advisors or stimulate other forms of knowledge transfer (e.g. in using collective forms of advice provision such as Living Labs) or trying to fill the gap in advice provision in the rapidly changing IT sector (e.g. in precision farming). Using these insights in scenario work later in the project will foster an identification of which particular steps could be taken by key actors to improve the role of FAS in innovation processes. In the remaining time of the project this will be further elaborated into concrete advice for various parties in the farming advice systems in different countries, as well as the EU level.

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A BUSINESS MODEL FOR INNOVATION SUPPORT SERVICES - IMPROVING INNOVATION CAPACITY BY DEVELOPING A BUSINESS MODEL BASED ON CONCEPTS OF PHYSICAL PROXIMITY, DIGITAL COUPLING AND SHARED COLLECTIVE INTELLIGENCE (WEQ)

Anita Beblek[a], Katharina Diehl[b]

[a] Agrathaer GmbH.
[b] University of Potsdam.

Abstract: Improving the Agricultural Knowledge and Innovation System (AKIS) has gained substantial attention during the CAP period 2014-2020. Innovation support services (ISS) and Innovation Brokers (IB) are considered to play a vital role in building bridges between different actors in the agricultural sector. By fostering co-creation they can e.g. support the quest for innovation to cope with the huge challenges the sector is facing, such as food security, climate change adaptation and mitigation or the over-exploitation of natural resources. However, the question remains how innovation system knowledge and ISS activities can safeguard these core functions within AKIS beyond the limited lifetime of funded projects like EIP-AGRI projects. In Germany a dedicated transdisciplinary team at the nexus of science and management conducted a dynamic and iterative management process to translate the strategic role of an ISS into a new business model for venture creation using a novel combination of business model elements. The business model elements were selected to create a) a financially sustainable support system for innovation, b) empower scientists, farmers as well as SMEs in the agri-food sector to develop new production and business opportunities, and c) generate socio-economic well-being and jobs in rural areas. They comprise concepts of proximity at the physical level, of digital coupling and of shared collective intelligence, thereby leading to a permanent cross-fertilisation of ideas, knowledge and experience between and beyond those actors (WeQ). The outcome was an ISS Hub organization in the Federal State of Brandenburg that has led to improved innovation activity level and the enhancement of the local AKIS. In this paper we describe the development of the ISS Hub organization to provide independent complementary services needed for improving and professionalizing knowledge and innovation transfer and commercialization from an action-research perspective. We assess how the resulting business model addresses the underlying issue of coupling by juxtaposing its main elements with the main characteristics of a system model for innovation given by Freeman as an outflow of the Maastricht Memorandum (1996). By outlining conceptual thinking behind the creation of an innovative business model for ISS we discuss how the individual elements foster their ability for knowledge transfer and increase their innovation capacity towards a faster adaptation within AKIS.

STRATEGIC FUNDING OF COMMUNITIES OF PRACTICE TO ACHIEVE POLICY GOALS: THE EXAMPLES OF MULTI-ACTOR INNOVATION PROJECTS IN THE FORESTRY SECTOR IN EUROPE

Rita Moseng Sivertsvik [a], Gunn-Turid Kvam [a], Katrina Rønningen [a], Robert Home [b]

[a] Institute for Rural and Regional Research (RURALIS), Norway.
[b] Research Institute of Organic Agriculture (FIBL), Switzerland.

Abstract: Sustainable solutions to complex socio-scientific problems, such as the rural exodus that is evident in many parts of the world, require mobilization of a growing range of stakeholders with multiple perspectives. Informal communities of practice (CoPs), with high degrees of autonomy in processes and activities, have formed to address such problems by enabling social learning, which can lead to co-innovation to implement joint visions and create solutions. Funding bodies have the potential to further their own agendas by supporting CoPs when the values of the CoP align with the funding body's goals, but they tend to prescribe processes and activities as a condition of funding, which is inherently top-down. This paper explores the possibility of using top-down funding instruments to support bottom-up programs to achieve mutually desirable outcomes. We focus on three cases in rural communities in Norway, Sweden, and Austria in which funding bodies have supported communities of practice in the forestry industry and analyze the projects in terms of their internal and external interactions. This approach of funding bodies supporting CoPs by negotiating specific outcome goals, while allowing a high degree of freedom of process, was found to facilitate the cases to be dynamic in their interactions. The dynamism enabled them to achieve outcomes such as collaborations to establish a competence center, an education program to showcase perspectives for girls in the forestry industry, and collaborations to find innovative applications for timber products. These outcomes each contribute to providing perspectives in the forestry industry for young people, which has implications for the viability of the communities and can contribute to stemming the rural exodus. We conclude that providing support to CoPs can indeed be used as a top-down tool to support bottom up processes to progress towards joint visions of desirable outcomes.

FARMER-LED INNOVATION NETWORK, AN EMERGING COMMUNITY OF PRACTICE IN THE UK

Lisa van Dijk[a,b], Beth Dooley[c], Steven Dunkley[d], Helen Aldis[e], Alistair Prior[f], Tom MacMillan[g], and Julie Ingram[h]

[a] School of Agriculture, Food and Environment, Royal Agricultural University, Cirencester, UK
[b] College of Life and Environmental Sciences, University of Exeter, Exeter, UK
[c] College of Social Sciences and International Studies, University of Exeter, Exeter, UK
[d] AHDB, Stoneleigh Park, Kenilworth, Warwickshire, UK
[e] Innovative Farmers, Soil Association, Spear House, Bristol, UK
[f] Scottish Rural Network Support Unit, Scottish Government, UK
[g] School of Agriculture, Food and Environment, Royal Agricultural University, Cirencester, UK
[h] CCRI, University of Gloucestershire, UK

Introduction

Policy context

Climate change, environmental degradation and increasing population growth are threatening our food systems (Foresight, 2011). Although great strides have been made, as crop and livestock yields have increased significantly since the 1960s, there is evidence that production is levelling off (Grassini, Eskridge and Cassman, 2013, MacMillan and Benton, 2013). Intensification and the extensive use of agrochemicals have created environmental problems (Steinfeld et al., 2006, Godfray et al., 2010) and more and more societal-ethical questions are raised about how food is produced, its quality, safety (e.g. antimicrobial resistance, BSE, salmonella, listeria) and animal welfare. Farming in the United Kingdom (UK) has gone through a process of transition from a '*productivist'* to a '*post-productivist'* regime (Wilson and Rigg, 2003). The role of farming in rural areas has changed from merely productive (production of primary goods) towards a multifunctional role delivering a range of public goods (Van Huylenbroeck et al., 2007, Van der Ploeg et al., 2000). This has now progressed towards concepts of public goods in UK (Bateman et al., 2018; RSA, 2019). Farming nowadays is conducted in an increasingly dynamic and unpredictable setting, in terms of market, policy, social and environmental circumstances and our thinking about research and innovation has evolved accordingly (World Bank, 2006, Hall, 2007).

For many years, the assumption in agriculture policy has been that scientists working in institutions and large enterprises are best placed to provide the innovations (technical solutions) to our policy challenges (Vogl, Kummer and Schunko, 2016). However, despite large investment, and big, centralised research projects focused on finding general answers or developing mass-market products, they struggle to support innovation to the farm context (MacMillan and Benton, 2013). Standard experimental methods, which rely on replication to rule out environmental difference, cannot cope with the complexity of whole systems (Cook et al., 2013). Thus, new approaches are needed to foster farmer innovation but draw on the body of scientific understanding. Over the years years, there is an increasing realisation that, to deal with the current challenges in agriculture, there is a need to go beyond linear models of knowledge transfer to processes of knowledge co-creation focusing on participation of multiple stakeholders, including farmers, and better use of knowledge to enhance sustainability (World Bank, 2006, Röling, 2009). This has led us to reassess innovation which is now seen as an iterative and evolving process involving interactions of many individuals and organizations possessing different types of knowledge in an innovation system, of which the linear model is a part (Hall., 2005). This co-innovation is now a preferred model for action research and innovation implementation (Dogliotti et al., 2014; Botha et al 2017). In this context, supporting research and innovation in farming systems requires working on real farms, drawing on scientific principles and environmental science and data. This entails recognising and supporting innovation *by* farmers, in partnership with scientists, rather than seeing them as customers for technology invented by others.

There has been a growing policy interest in agricultural innovation generated through these collaborative knowledge creation processes involving both scientists and farmers, both within the UK and at European level (Brunori et al., 2013). The European Innovation Partnership has been promoting the interactive approach to innovation through the EU H2020 multi-actor approach and Operational Groups of the Rural Development Programme which both include a high level of practitioner engagement (SCAR, 2013). Farmer-led innovation initiatives (formal and informal) have had an increasing presence in the UK AKIS since the privatisation of advisory services, responding to a shift towards more farmer-centred thinking and opportunities for support (Garforth et al., 2003, Dwyer et al., 2007, Curry et al., 2012). This has been in line with a general ethos to support collaborative mechanisms and incentives to foster group activities such as catchment and landscape partnerships, agri-environment co-operative schemes, as well as informal farmer cooperative activities. The DEFRA 'Health and Harmony: the future for food, farming and the environment in a Green Brexit' (2018) consultation states, '*We want to explore how collaborative research ventures, involving farmers and other partners (such as research syndicates) can develop a new generation of agricultural technology. This would enable farm businesses to work together to overcome common challenges through bespoke technological solutions*.' It continues, '*There is an important role for knowledge sharing, producer cooperation, and farmer-to-farmer learning to kick-start a wider culture of excellence.'* Hence, opportunities exist for the enhanced integration of more participatory approaches to farmer-led research and innovation in future strategy and policy initiatives.

Farmer-led research and innovation

Farmer-led research and innovation (practice-driven or practice-led) is a process through which farming practices are developed on farm, either through individual or collective action, with suitably applied science input, and directly and indirectly shared amongst farmers, to inform both science and the wider stakeholder community (retail, food service, government and others). Farmer-led innovation can be either challenge-led or opportunity-led and responds to the demand for innovation to solve local problems using practical knowledge and creativity at the farm level and (Vogl et al., 2016). Akrich et al. (2002, p. 202) argue, '*the evaluation of the disadvantages and advantages of an innovation is entirely in the hands of the users: it depends on their expectations, their interests, on the problems, which they* raise'. Farmer-led innovation is derived directly from the '*rooted*' experiences of '*doing*', their practice, to cope with and adapt to the challenges faced in everyday as well as strategic contexts (Hoffmann et al., 2007). The word 'innovation' (singular), refers to a process of on-farm practice change, including changes in resource use, outcome (animal), farm management, relationships (social), market and policy and includes either developing new ideas or using existing ideas for a new purpose and/or in a new (specific farm) context (Conroy et al., 2008). This definition goes beyond the traditional thinking of what constitutes innovation. Traditional thinking focuses on innovation as merely technological solutions; however, increasingly other types of innovation, such as innovation in social and institutional arrangements, are recognised (Conroy et al., 2008).

Paradoxically, this in-practice and on-farm demand for innovation is rarely seen as a major driving force for applied science research. The call for innovation does not emerge from scientific research processes but emerges from the social interactions and cultural context of individual farmers with varying management practices operating within their communities. Enabling and mobilising this demand requires creating space for joint learning and knowledge sharing, bringing together farmers and different actors, with different (forms or sources of) knowledge (Spielman and Birner, 2008, Moschitz et al., 2015, McKenzie, 2013). Intermediary organisations or

Innovation Support Services facilitating such processes typically use participatory approaches and are funded through a variety of sources.

The UK has been at the leading edge of new initiatives that put farmers in the driving seat, supporting them to work together and with scientists on their own terms. Pioneering initiatives include Innovative Farmers[10], the ADAS Yield Enhancement Network[11], Rothamsted's FarmInn programme[12] and Scotland's Rural Innovation Support Service[13]. Pilot funding from UK Research and Innovation (UK Research Councils), the levy boards and government has helped make this possible. A private foundation, the Prince of Wales's Charitable Fund, has been the largest investor in this sector to date. However, there has been limited cooperation and coordination between the intermediary organisations supporting these processes, hence, there is a risk of fragmentation of the support landscape. Moreover, with the potential increase in funding opportunities encouraging more farmer-led approaches, there is a need to build the capacity of existing and new organisations supporting these types of initiatives, ensuring the use of tried and tested best practice and avoidance of past replicable mistakes.

At the end of 2018, the Farmer-Led Innovation Network (FLIN) was established to tackle the above-mentioned challenges. This network can be described as a Community of Practice (CoP) in that it is a group of people informally bound together by shared values, expertise and passion for a joint enterprise (Wenger and Snyder, 2000). This paper presents the results of the ongoing work of this CoP and the opportunities and challenges involved with operating as a network over the past year.

The Farmer-Led Innovation Network

Aims and objectives

The Farmer-Led Innovation Network (FLIN) was established in the UK in October 2018 to share knowledge and experiences and provide a collective advocacy voice for farmers directly involved in these initiatives. The establishment of this network of intermediary organisations was inspired by the PROLINNOVA (Promoting Local Innovation) network (Waters-Bayer et al., 2004). The main aim of this network is to understand, learn from and 'power up' farmer-led innovation initiatives in the UK and increase the impact of these kind of initiatives across the industry. The network objectives are:

Work collaboratively to advance farmer-led innovation and research in the United Kingdom.

Share best practice and support each other, as necessary, to enable each member to enhance and promote farmer-led innovation and research.

Promote concepts, which put farming in the driving seat and support and normalise research with impact.

Develop projects and/or programmes together, as appropriate, to maximise the impact of the network.

Currently, over 20 organisations involved in farmer-led innovation and research initiatives are part of the network, including governmental, non-governmental organisations, research institutes, the levy board, farmer organisations and advisory services. The network brings together initiatives directly representing farmers involved in farmer-led innovation across the UK;

[10] https://innovativefarmers.org/
[11] https://www.yen.adas.co.uk/
[12] https://www.rothamsted.ac.uk/farminn
[13] https://www.innovativefarmers.org/welcometoriss

an estimate of at least 1500 farmers directly involved and over 3,000 farmers in initiatives engaging farmers in like-minded types of processes but with a less specific focus on innovation. Around £2 million of pilot funding from public, third sector and industry R&D has been invested to date and in some cases, the initiatives also leverage in-kind contributions, for example, from scientists or input providers. None of the initiatives routinely quantify in-kind investment by farmers but, extrapolating from examples where they have done so, they estimate this to at least match the level of cash funding indicated above.

Outcomes sought and activities

With the increasing interest in these types of initiatives, there is a need to build the capacity of organisations supporting these types of initiatives. Hence, the network is collectively working through workshops, working papers and commissioned research on:

Development of better, more structured and monetised evaluation of the success and effectiveness of these types of initiatives to provide evidence for policymaking. The network is working on harmonising data sharing and consistent use of benchmarking services across a diverse range of farmer projects (and contributing to the development of those services) to support cross-community meta-analyses.

Skill development for innovation facilitators and researchers to work effectively with farmer groups and increase the number of advisors and researchers involved in these initiatives. The network collectively provides workshops and training for innovation facilitators and researchers to improve their facilitation skills in these collaborative learning processes.

Sharing and documenting best practice, drawing on the knowledge and experience of the organisations involved to develop working 'standards' or principles to ensure effective engagement with farmers and relevant actors.

In the first year of the network, two network meetings took place, one face-to face and one virtual, and several workshops were organised to share experiences, including an Innovation Facilitation workshop. Initial work was commissioned on the development of better, more structured and monetised evaluation of the success and effectiveness of these types of initiatives, and a policy-influencing workshop was held to share experiences of designing farmer-led innovation funds and support services with policy makers.

Organisational structures and roles

Network membership is open to any organisation involved in farmer-led research and innovation in the UK and new members can be proposed by any existing FLIN member. Although the intention was to have no formal membership and have a fairly loose affiliation of individuals, in the first network meeting it was decided that for the network to function and create an identity, some sort of agreement needed to be in place between its members. A membership Terms of Reference (ToR) was developed; however, these ToR did not create any binding obligations on or between any of the FLIN members and were merely established to clarify the objectives, roles and responsibilities involved with FLIN membership. They also included consent to use the logos and organisational names of network members for FLIN communication and promotional purposes. The membership ToR did not commit FLIN members to any specific level of engagement in the network, the level of participation was completely based on individuals' and/or organisations' time and interest; the ToR also did not commit members to fund or support any FLIN activity. FLIN members agreed to meet together at least twice a year, either face-to-face or virtually, to discuss FLIN activities. To better manage the activities carried out under the ToR, the members agreed that any activities to be carried out by FLIN will be managed by a Steering Committee appointed for a period of two years.

Challenges and opportunities for intermediary organisations supporting farmer-led innovation in the UK

The work of FLIN in its first year generated several insights into the challenges and opportunities that intermediary organisations supporting farmer-led innovation and research in the UK face.

Developing farmer-led initiatives takes time and effort

During the network inception meeting, it became clear that amongst members there is a diverse mix of farmer-led initiative 'models' with different goals, audiences and funding structures. Initiatives can be plotted across a spectrum from those characterised by close facilitation of small groups that meet on a regular basis and informally steer the topics through to those characterised by formalised activities and large networks with farmer involvement. At one end of the spectrum, they are funded through public, NGO support, whilst at the other they are funded through industry support. Recognising this diversity may bring challenges for the network in terms of different initiatives having different support needs; however, this diversity also brings opportunities in terms of benchmarking performance amongst members and learning which 'models' work well or better under certain circumstances and contexts. Regardless of this diversity, the network members advocate that these initiatives harness farmers' ingenuity to benefit the whole industry. Many of the initiatives were designed as pilot projects and programmes to develop models that could be upscaled and network members indicated it takes time and effort to develop these types of projects. Not only does it take time to initiate these on the ground in terms of working with farmers (relationship building amongst the group and with the facilitator and creating a common vision), but also to develop capacity within their organisation to manage and coordinate these types of initiatives effectively. Part of the objective of FLIN is to support each other, as intermediary organisations, to develop this capacity collectively.

Facilitating farmer-led innovation: emerging new roles, new relationships, and new skills

At a meeting of FLIN in February 2019, a session was held to identify the skills required and current practice in facilitating innovation. Following this meeting, a one-day Innovation Facilitation workshop was held in July 2019. During this event, drawing on the expertise of FLIN members and their networks, participants further explored and shared best practice in facilitating farmer-led innovation to identify the skills and competencies required to effectively facilitate innovation. This led to an agreed action plan for capacity development for FLIN members in this area. Most of the initiatives involve a facilitator, who range from scientist such as agronomists and vets to farmers and knowledge exchange officers. Often, this facilitator is involved in multiple initiatives. From the workshop, it was clear that there is an abundance of potential facilitators available, so that was not likely to be a limiting factor; however, a lack of facilitators skilled in supporting innovation projects by farmers may be a limiting factor. Often, the facilitator has facilitation skills in running events or meetings, but limited skills in the practicalities of developing farmer groups and in facilitation for group action. The network members indicated that the quality of support for and from facilitation varies within the current initiatives, so training and capacity-building should be a priority.

Discussions further revolved around the role of a scientists in farmer-led processes. It was recognised that in these processes, farmers' and scientists' roles have changed and these initiatives have created new (and often more complex) relationships between scientists and farmers based on experimental learning and co-production of new solutions. Farmers are valued for conducting their own experiments and are now partners in co-innovation processes, whilst scientists support the innovation process, often with an enabling or facilitating role. Both acknowledge the joint contextual knowledge developed through the innovation process, which emerges as a collective rather than the individual property of the scientist. Facilitation of these processes requires skills scientists may not necessarily have gained through their academic careers and provides a diverse range of opportunities for scientists to understand and respond to industry priorities, as well as make their previous research relevant and accessible to farmers.

The question on measuring effective facilitation was explored from the perspective of facilitators, farmers, and support organisations. Group discussion revolved around the need for the facilitator to create space for learning, their ability to guide farmers in the co-creation process of developing solutions to their real-life problems, unlock the collective knowledge within the group, generate the energy for action, and stimulate self- and group reflection on their performance. The session recap asked each group to present their top three key insights from the group discussion about monitoring and evaluation (M&E) and potential indicators for effective facilitation, see Table 1.

Table 1. Top three insights from the group discussion about M&E and potential indicators for effective facilitation

Facilitators	Farmers	Organisations
1) Be clear about your own expectations 2) Identify where people are in the innovation spiral[14] 3) Develop a decision tree so you can self-assess, engagement, learning, idea generated, and the energy of the network	1) Measure success by what they need 2) Measures could include involvement, ownership, willingness to pay, sustained involvement (motivation to continue), change. Not one size fits all measures and M&E methods 3) Get farmers to define what successful facilitation looks like and use to this to evaluate	1) At programme level, attributing success to the facilitator is hard 2) Evaluate how you coordinate innovation as a whole 3) Consider different types of learning, not just farmers/facilitators, also reflective process at the organisational level

Evidencing impact

There are multiple methodologies available for evaluating farm-led initiatives and this is an area of interest for the CoP. In general evaluation approaches can measure, understand or learn (Berriet-Solliec et al., 2014). Whilst policy makers prefer measurements of for example practice change or acquired knowledge as evidence of an effective initiative, this approach rarely captures the learning and reflection that occurs amongst all actors in such initiatives. One of the main challenges in enhancing farmer-led innovation is the limited UK evidence of the success and effectiveness of these types of initiatives for policymaking. In the first year of FLIN, some initial work was commissioned to map the M&E approaches of FLIN members, Table 2. Preliminary results showed that members undertake a range of in-house or independent external evaluation, which may be available from them on request, and also publicly report project findings. For example, the latest independent evaluation of Innovative Farmers found that (of the full membership, not those directly involved in projects): 98% of farmers would recommend membership, over 75% have learned something new and over 50% either have made or are

[14] The spiral of Innovations p 61 in Wielinga,et al. (2008).

planning changes to their business as a result (Reed et al., 2016). Recent projects have generated farmer-relevant insights on issues such as productivity of intercropping; drone use to predict potato yield; iron deficiency effects on growth in dairy calves; herbicide-free min till systems; and phosphate availability. However, although there was overlap in the success of FLIN members' initiatives, comparability was limited due to use of different methods and/or metrics to monitor and evaluate their implementation and impact.

Table 2. The diversity of monitoring and evaluation approaches that FLIN members reported.

	Methods	Metrics
Monitoring	Reporting against milestones *Options: monthly / quarterly / annually*	Uptake and growth *Options: increasing participation, event / training attendance*
	Data collection *Options: automated, participatory, facilitator, online/hard-copy*	Learning and change *Options: implementation of plan, change in management practices*
	Participant feedback (surveys) *Options: event-based, per season/project cycle*	Performance *Options: benchmarking (financial), quantitative results*
Evaluation	Qualitative and quantitative (both in the approach and data collected) *Options: semi-structured interviews, questionnaires, participatory assessments, telephone surveys, quantitative feedback forms*	Evidence base aligned with aims & objectives *Options: qual/quant results on increases / decreases / changes in management practices desired, quality of experience for individual participant / event attendee*
	Formal vs informal *Options: structured against long-term objectives, short-term milestones*	Difference made / measure of effectiveness *Options: benchmarking results improved, learning demonstrated*
	Independent *Options: internal / external*	Mechanisms / cause & effect *Options: participatory process impact on technical implementation and uptake*
	Timing *Options: designed from initiation of programme/project, set intervals, forward-looking (2- to 5- to 10-years time)*	

Often farmers mention clear benefits in terms of changing the way they think about farming and trying new practices. Unfortunately, network members indicated they often lack the structures for assessing these gains against their objectives. There is also a wide variation in the methods used to gather feedback and results amongst the FLIN members. Another challenge mentioned was the short project spans over which to measure change; members indicated change may take longer than the project or be an ongoing process, so short-term measurement may not demonstrate that. Qualitative data is also often highly context dependent, hence, its limited scope and generalisability between farms.

Based on this initial mapping, in the coming year further work will be done on harmonising data sharing and consistent use of benchmarking services across diverse farmer projects (also contributing to the development of those services) to support cross-community meta-analyses. This is aimed at allowing initiatives to compare and assess where improvements can be made, reduce cost by pooling resources, promote best practice and use approaches that others have tried and tested as practical and effective rather than spending time, money and effort reinventing the wheel. Although participatory evaluation methods were preferred by network members, they recognised the need for external evaluation in order to influence policy as it strengthens the robustness and validity of the findings and potentially benefits from comparative analysis. Robust, consistent evaluation evidence is important when making the case to research funders and policymakers that farmer-led initiatives can meet their objectives and warrant their support.

Public and private investment priorities

Funding from various public and private sources has helped to make these farmer-led initiatives possible. Comparing their investment to the overall R&D investment budget in the UK, investment in experimentation and innovation in farming systems and methods, particularly farmer-led innovation and research, is still very little. One of the objectives of the network is to influence policy and include this type of research as part of mainstream R&D investment. From the start of the network, policymakers were involved and attended network meetings and other activities. Several network members also spend time working with policy makers and provide direct support in the design and development of new policy to include these types of approaches. Relative to overall public investment in agricultural R&D, the cost and risk would appear low, the potential impact high, fast and directly attributable, and the potential public return on investment highly favourable (Frontier Economics, 2014). The public value of this investment will derive not only from the improved economic performance of a sector that currently receives billions in taxpayer support, but also through innovation that restores natural capital and delivers ecosystem services. Policies designed to encourage farmer-led innovation approaches should measure this return on investment and aim to exceed private and public rates of return from established agricultural research (Salter and Martin, 2001).

Scaling up farmer-led innovation in the UK

Several of the initiatives in the network have been deliberately designed as pilot projects and programmes to develop models that could be upscaled. Whilst a key lesson from members' experience is that it takes time and effort to develop farmer-led projects, the main factor limiting their scale has been the availability of funding, including funding for that development time. With more funding available, organisations involved in FLIN are confident they could grow significantly, with proportionate increases in impact. Key question is, though, *how far could such models really be upscaled*, *how many farmers could realistically be engaged*? Furthermore, farmers are not a homogeneous group, so their willingness, interest (motivation) and time to engage in these processes varies widely. Based on existing levels of engagement in wider, likeminded initiatives, as mentioned previously, it seems plausible that at least 5,000 farmers in the UK would potentially have an interest in participating in innovation projects.

More so than the potential availability of interested farmers, the practicalities of developing farmer groups seem likely to limit growth. The current initiatives have mostly developed over the past 2-5 years, amidst an uncertain patchwork of funding. With a more predictable funding environment, it seems plausible that growth could be accelerated. Moreover, the availability of facilitators and researchers skilled in supporting innovation projects by farmers may be a limiting factor, with the quality of support varying even with the current initiatives, so there should be a priority for training and capacity-building. To answer the question *how far could such models really be upscaled* would realistically rely on a steady increase in available funding for projects, sufficient investment in project development, and additional support to build capacity amongst facilitators and researchers. In practice, the design of fund schemes and accompanying innovation support should accommodate collaboration on diverse scales, including larger networks of farmers working together on the same topic. Tools such as Agronomics and Innovative Farmers' proposed protocol packs enable this. New technologies in precision engineering, remote sensing, big data and breeding offer exciting opportunities for a new generation of agricultural inputs that are more resource efficient. However, the truly revolutionary potential lies in putting farmers, and the citizens they ultimately provide for, in the driving seat of changes to farming and food systems (RSA, 2019).

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LINKS BETWEEN THE ADVISORY SYSTEM BUILT BY DAIRY FARMERS AND THEIR REPRESENTATIONS OF THE AGROECOLOGICAL MANAGEMENT OF ANIMAL HEALTH

Eulalie RAMAT [1, 2] ; Lucie GOUTTENOIRE [1] ; Nathalie GIRARD [2]

[1] Université Clermont Auvergne, AgroParisTech, INRAE, VetAgro Sup, France
[2] Université Toulouse, INRAE, UMR1248 Agir, Castanet-Tolosan, France

Abstract : Today's farming is subject to various political, economic, and social expectations on practices. In the case of dairy production, farmers must face the challenge of ensuring quality milk production while improving their practice in an agroecological way by, for example, reducing their use of chemical medicines. These new challenges imply developing new knowledge and skills for farmers in order to create their situated health management, while there is no shared representation of what is or should be an agroecological health management among the agricultural knowledge and innovation system (AKIS). In farms, many agricultural extensionists (veterinarians, but also technical advisors, processors...) individually help farmers in animal health management and in learning new practices. We thus choose to think of such sets of professionals as “advisory systems” built by farmers. We assume that famers choose health prescriptions according to their own representation of what means a healthy herd and what should be health management. The question remains on how each farmers build a coherence between the multiple prescriptions they receive from their advisory systems and their own representation. Our objective in this paper is to investigate both the advisory systems and the socio-cognitive representations farmers have of health management and to evaluate to what extent they match or not. We conducted in-depth interviews with dairy cattle farmers in the Massif Central Region (France), chosen for their engagement in agroecological management of animal health. We then carried out a qualitative analysis of the speeches, exploring the relationships between each farmer and his advisors, and how they think and manage health. Using the repertory grid tool, we identified a typology of advisory systems modeling the various organizational forms built by farmers regarding the social and cognitive distribution of advising for their health management. In parallel, we formalized the different ways of thinking and managing animal health farmers endorsed by identifying their aims, conceptions, beliefs, rules and practices related to animal health management. We then discuss the links that we see between the socio-cognitive representations of agroecological health management and the forms of advisory systems. The links we made open avenues to investigate the socio-cognitive development of farmers in their engagement in an agroecological management of animal health, and the conditions in which they may learn to be more autonomous in these agroecological practices. This will also raise some important highlights regarding the potential synergies between advisors, and their training about agroecological animal health management.

THE ROLE OF DIFFERENT TYPES OF ORGANISATIONS SUPPORTING INTERACTIVE INNOVATION IN AGRICULTURE AND FORESTRY

Susanne von Münchhausen[a], Gerlinde Behrendt[b], Evelien Cronien[c], Andrew Fieldsend[d], Anna Häring[f]

[a] Eberswalde University for Sustainable Development
[b] Eberswalde University for Sustainable Development
[c] EV-ILVO
[d] AKI
[f] Eberswalde University for Sustainable Development

Abstract: A large variety of organisations provides support for cooperative approaches in the field of research and innovation in agriculture, forestry and rural development, and acts as Innovation Support Services (ISS). The findings from ProAkis (2015) show that different types of organisations such as administrative offices, public or semi-public advisory services, rural academies/universities, producer organisations, other NGOs or private consultants engaged in the Agricultural Knowledge and Innovation System (AKIS) can act as ISS. The funding of ISS can be public, private or a mix of both. A first literature review indicates that studies often focus on the larger "enabling environment" and the structure of the Agricultural Knowledge and Innovation Systems (AKIS). Moreover, many authors pay particular attention to the role of public or semi-public advisory organisations (Knierim et al., 2015; Sulaiman 2015). The aim of this paper is to assess the different types of organisations that provide support for interactive innovation, and to analyse the particular role of each type of organisation for interactive innovation projects. Particular attention will be payed to the divers group of organisations that are not part of a (semi)-public advisory organisation. The paper is based on the analysis of more than 200 case studies of publically or privately funded interactive innovation projects within the EU and beyond. The selection of cases took place under the framework of the project LIAISON funding by the EU research and innovation programme Horizon 2020 (grant agreement No 773418). European and national databases contain several thousands of projects in agriculture, forestry and rural development. We selected projects applying the interactive innovation approach from a) EU programmes (EIP-Agri, Horizon2020, Interreg, and LIFE+); b) nationally/regionally or privately funded projects; and c) informal initiatives or networks in the agri-food, forestry, bioeconomy or nature conservation area. Preliminary results indicate that publically funded IIS play a core role for legal/administrative compliance of projects. Semi-public advisory services take up this role as well, and they are strong in linking farmers with scientists, technicians, entrepreneurs etc. However, they often exist and offer efficient ISS only for those industries that have a long tradition for a sector or area (e.g. dairy, pork, poultry or club fruit). Niche sectors or industries with little policy engagement often lack the support of a publically funded advisory service but profit more from producer organisations or rural academies/universities when they take up the role of ISS.

THE LOGIC OF INNOVATION: EXPLORING THE ROLE OF INSTITUTIONAL LOGICS IN SHAPING INNOVATION IN AUSTRALIAN AGRICULTURE

Sean Kenny[a], Ruth Nettle[a], Jana-Axinja Paschen[a], Michael Santhanam-Martin[a]

[a]School of Agriculture and Food, Faculty of Veterinary and Agricultural Sciences, The University of Melbourne, Melbourne, Australia.

Abstract

The rationale informing innovation investments in Australian agriculture is one which views innovation as the source of productivity growth. Productivity is a measure of how efficiently inputs are converted to outputs, with the benefits of this efficiency theoretically being passed on to society through higher incomes which in turn deliver a range of societal benefits. Since the early 2000's Australia generally has experienced an extended period of low productivity growth which can be observed in stagnating median household incomes. More specifically, productivity growth in Australian agriculture has been the lowest of almost all OECD countries over the last 2 decades.

There are three key drivers of productivity growth which the Australian productivity commission describe as immediate causes, underlying factors and fundamental influences. Current 'innovation investments' typically target immediate causes. Workers in the field of agricultural innovation have been grappling with how best to sustainably address the productivity challenge in the face of an increasingly complex operating environment for nearly a century, with systems approaches having evolved as a direct response to this challenge.

The history and traditions of innovation in agriculture and the emergence of systems approaches can be viewed as an expression of different views on how the world works, how knowledge is generated and communicated and how best to solve problems. We equate these 'worldviews' with the 'underlying factors and fundamental influences' which the productivity commission suggest shape productivity performance.

In this paper we outline how these 'underlying factors and fundamental influences' may be influencing innovation performance in agriculture and by extension its sluggish productivity growth given the way in which institutions shape all aspects of human agency. A conceptual framework is proposed which has been designed to inform exploration of competing 'institutional logics' in Australian agriculture, with a view to enhancing change mechanisms and refining roles of relevant actors within the Australian AIS.

The Productivity problem in Australia

The vast majority of documentation concerning innovation in Australia outlines a chain of logic along the lines of the following quote:

"Investment in research and development (R&D) and innovation is vital for ongoing growth and improvement in the productivity, profitability, competitiveness and sustainability of Australia's agriculture, fisheries, forestry and food industries. " http://www.agriculture.gov.au/ag-farm-food/innovation.

This logic, even if it is not clearly stated, goes like this:

Invest in science/innovation, which will……

…… deliver economic growth through productivity gains, which will…….

…….lead to greater prosperity and living standards.

Sometimes there is a pivot toward the social and environmental elements of sustainability, such as this from the chair of Innovation and science Australia:

"Since the dawn of civilisation, innovation has driven human progress. What many take for granted - the elimination of diseases such as polio and smallpox, breakthrough antibiotic treatments such as penicillin, safe and efficient travel courtesy of the jet engine, individual access to computing and communications power within a hand-held device—all of these benefits have been delivered by innovation."(ISA, 2016)

This broader view which places social progress at the centre of innovation is refreshing, but sadly the gravitational pull of the economist cannot be resisted, as in the next breath, the chair notes:

"Innovation is an essential driver of productivity and economic growth; hence governments around the world are grappling with how best to encourage and support more of it."(*Ibid*)

So the interest in innovation currently in Australia relates to the way in which it, as a process of change and transformation, delivers to us gains in productivity. *"The best summary statistic for our success in embracing new and better ways of doing things is productivity growth."* (Cutler, 2008)

Steindel and Stiroh (2001) describe the two main measures of productivity. Labour productivity in its simplest form is defined as real output per hour of work. Total, or multi factor productivity (TFP and MFP) is defined as real output per unit of all inputs. They go on to state that three primary factors determine growth in productivity. Capital deepening reflects the increase in output from physical capital available to workers. This largely speaks to the equipping of a workforce. The second element is labour quality, which attempts to capture the increase in output resulting from a change in worker mix or skills. The third contributor to productivity growth is total or multi factor productivity growth, which effectively measures the increase in output not attributable to capital deepening or labour quality. So how is Australia tracking on these measures? According to Cutler, (2008), not so good:

"Sometime around 2002 Australian productivity went from growing substantially faster to growing substantially slower than the Organisation for Economic Cooperation and Development (OECD) average. Though some of this may be an artefact of increased mining investment, it is unlikely to be the whole story. The conclusion is that, had it not been for the hunger the emerging giants of the developing world have had for our resources, we would have felt the effects of our complacency more directly as stalling living standards."

The trend noted by Cutler in 2008 has continued for the last 10 years. Whilst labour productivity has continued to show relatively typical, cyclical variation[15] MFP growth has been subdued for almost two decades[16]. Median household incomes have also remained virtually unchanged for more than a decade[17]. Whilst there is not a tight relationship between these three indicators given that labour productivity has shown some significant growth over the last 10 years, the overall picture that emerges is one of low productivity growth and limited or no average wage or income growth.

When looking at the case of agriculture, the story is much the same. USDA international productivity data show a declining trend in TFP over the last 30 years (Figure 1). Data from the Australian Bureau of Agricultural Resource Economics and Sciences (ABARES) provides a more nuanced look at sectoral contributions to productivity growth within the broadacre industries,

[15] https://www.ceicdata.com/en/indicator/australia/labour-productivity-growth
[16] https://www.abs.gov.au/AUSSTATS/abs@.nsf/mf/5260.0.55.002
[17] https://www.abs.gov.au/household-income

and while showing glimmers of hope, the overall picture is one of low growth over the last 30 years, averaging 1.6% (Sheng, Nossal and Ball, 2013).

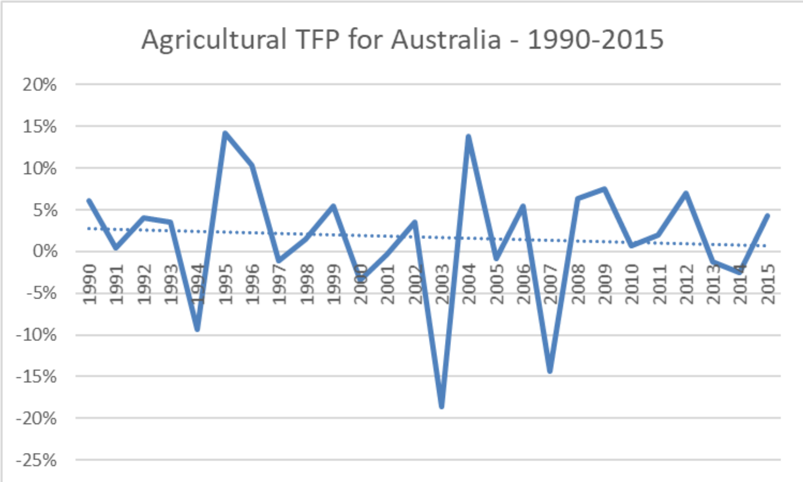


Figure 1: Total Factor Productivity Growth in Australia between 1990 – 2015. Source: https://www.ers.usda.gov/data-products/international-agricultural-productivity/

This being the case, the question needs to be asked: why the poor performance? Some may be explained by adverse seasonal conditions, however Hughes *et al.* (2011) through their exploration of climate adjusted productivity frontiers in the Grains sector, demonstrated that whilst climate variability impacts upon productivity, the trend of poor productivity performance since the early 2000's holds. Besides, Australia is not the only nation where its agricultural sector is beset by climate and structural challenges, and these challenges have not suddenly materialized since 2000. Whilst these may play a role, it does not explain the relatively poor performance when Australian agriculture is compared internationally. Figure 2 uses USDA productivity data to compare countries from around the world with regards to productivity growth over time. As can be seen, Australia has been one of the worst performers over recent times. A key point to note is the relative fortunes of Australia versus the Netherlands. This data shows the exact opposite performance over the two time series, with Australia achieving an average growth rate between 1990 and 2002 of 2.7% compared to the Netherlands 0.8%, whilst for the period 2003-2015 Australia achieved an average growth rate of 0.7% and the Netherlands 2.5%.

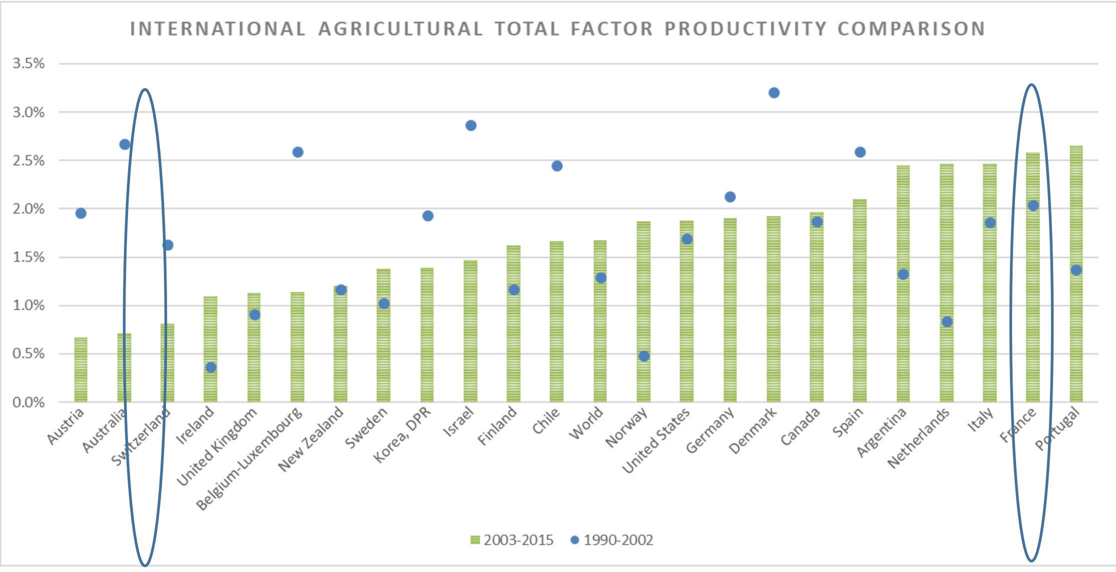


Figure 2: International comparison of average growth in total factor productivity for two times series – 1990-2002 and 2003-2015.
*Source:*https://www.ers.usda.gov/data-products/international-agricultural-productivity

So does this poor productivity performance mean we are not 'innovating'? The productivity commission identify three primary drivers of productivity change as summarised in Figure 3.

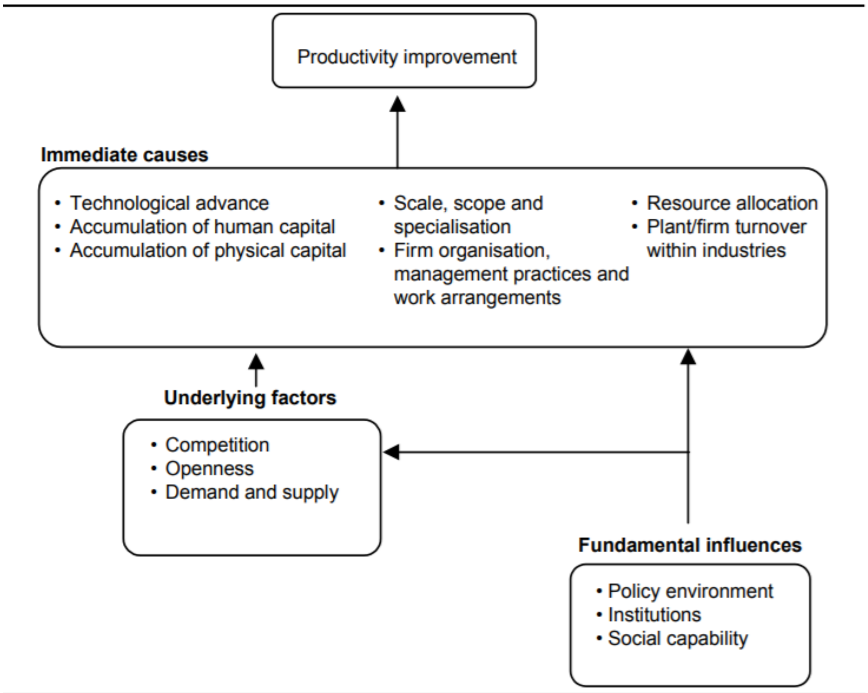


Figure 3: Main influencers of productivity growth.
*Source:*https://www.pc.gov.au/research/supporting/productivity-growth/productivity-growth.pdf

'Immediate causes' relate to the development and enhancement of technology, skills, knowledge and practices that shape and underpin organisation and firm performance. Underlying factors relate to the drivers of change, whether they be market signals or other incentives/constraints. Fundamental influences *"condition productive potential and its long term realization"*(Productivity Commission, 2009). The policy settings, institutional 'rules of the game' and orientation of the population toward change, all dictate both the starting point and trajectory of change. Thus when looking for reasons as to the poor productivity performance in Agriculture, all three of these influences need to be examined.

Over the last 10 years, numerous reports and strategies have been written to do just this. (The Council for Rural Research and Development Corporations, 2018, Australian Academy of Science, 2017, CSIRO, 2017, Food Innovation Australia Ltd, 2017, Australian Trade Commission, 2017, Millist, Chancellor and Jackson, 2017, Keogh and Henry, 2016, Australian Government, 2015, Hajkowicz and Eady, 2015, OECD, 2015, Cutler, 2008,). From these reports a number of key issues can be identified (Howard Partners, 2018):

Market and technology opportunities are presenting themselves yet there are a range of barriers to exploiting these

Investment in agricultural research and extension is declining

Insufficient product differentiation in global markets

Limited value adding and participation in global value chains

Human resource constraints leading to reduced uptake of technology

Increased questioning of social licence to operate in agriculture

Impacts of climate change will significantly impact agriculture

Inadequate digital infrastructure and services

Lack of support for the development of specialist suppliers in the technology space

Inappropriate research governance leading to short term focus and a lack of systems perspectives

These reports extend back more than a decade. Industries have had access to their wisdom and have continued to invest considerably in innovation activities, presumably whilst taking into account the insights presented. Depending on the estimates used, investment in the agricultural innovation system in Australia amounts to between \$3 and \$3.5 billion dollars annually (Millist, Chancellor and Jackson, 2017; Department of Agriculture, 2019). Based on the annual reports of the 14 rural research and development corporations and the 2018/19 federal government budget tables, the combined investment of federal government and industry levies is \$901 million. Once state government investment is added, approximately 62% of all investment in research, development and extension can be classified as 'publicly funded' if levies are included (Millist, Chancellor and Jackson, 2017). In light of the number of reviews and strategies developed over the last decade, and the ongoing poor productivity performance of Agriculture, it could be argued that levy and tax payers are not getting value for money out of a system which seems unresponsive to change.

Making progress on the productivity problem in Australia

Two potential 'reasons' for this poor performance can be articulated:

The agricultural innovation system is failing to achieve improvements in productivity because of an inability to adequately influence the 'immediate causes' of productivity. *This could be seen as a failure of method – ie: how innovation investments are defined, designed, managed and delivered.* Or;

The agricultural innovation system is not adequately addressing the 'fundamental influences' of productivity which underpin the capacity of actors in the system to influence 'immediate causes' of productivity. *This could be seen as a failure of those within the AIS to engage with and address root causes and reorient perspectives, approaches and structures associated with agricultural innovation accordingly.*[18]

The position taken on this reasoning has significant implications for policy and practice. If the key limiting factor to achieving innovation and associated productivity improvements relates primarily to the approach to innovation, then the response is to change the approach. If its to do with the 'fundamental factors' which influence all elements of the system, the response is to explore shifting the 'logic' which underpins the system and effectively change the way actors in think about innovation entirely.

The aim of this paper is to explore proposition 2 in more detail, through examining the history and traditions of innovation in agriculture; examining the area of 'fundamental factors' more closely and linking these to institutional theory, and finally, propose a framework through which institutional logics in Australian agriculture can be understood and used to enhance innovation performance.

The history and traditions of Innovation in Agriculture

Since the second half of the nineteenth century, where research stations were seen as the 'generator of knowledge' which was then 'extended' into the farming community, the evolution of perspectives on innovation can be distinguished by 7 key characteristics as follows (adapted from Röling, 2007; Klerkx, Van Mierlo and Leeuwis, 2012):

Underlying rationality

Theoretical perspective

Mental models

Focus

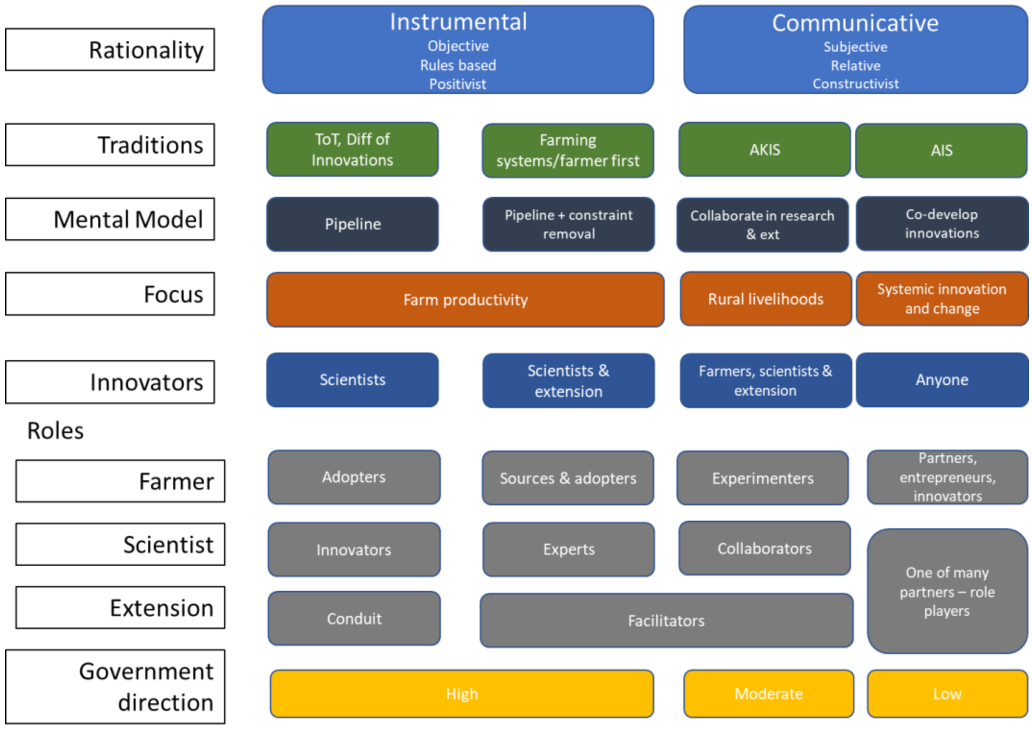
Perspective on who innovates

Roles of key actors

Level of government direction

The table below summarizes how each of these traditions differs in relation to these defining characteristics:

[18] There is a third consideration here, which is that productivity is a fundamentally flawed metric for innovation. Whilst not part of this current discussion, further analysis of this proposition will occur throughout the life of this PhD research.



The perspectives outlined above represent not only different traditions of innovation, but also different orientations toward what the means and ends of innovation might be. The progression toward the right of the summary diagram - in thought and theory at least - represents an increasing appreciation of the world as 'complex' and its problems as 'systems' in nature. However the idea of 'systems' approaches is not new, rather is *"a contemporary expression of perennial problems which have been recognized for centuries and discussed in the language available at the time."*(Von Bertalanffy, 1972). With regards to Agriculture, Bawden (1995), writing retrospectively on the evolution of systems approaches in the 1970's, commented that the problematic situation in agriculture during that period was characterised by an "ever increasing complexity". This drove the academics within the department of rural development at Hawkesbury Agricultural College to radically transform their curriculum to make it more 'systems oriented'. Complexity can be seen as a fundamental characteristic of agricultural systems (Bawden, 1991, 1992; Crawford *et al.*, 2007; Klerkx, Aarts and Leeuwis, 2010; Turner *et al.*, 2017). In fact, it is an attribute of all systems (Boulding, 1956; Checkland, 1981) and is therefore a defining feature of work focused on the improvement of problem situations.

Complex and therefore systems 'problems' present a problem to science. Von Bertalanffy, (1972) again:

"Science, however, was not well prepared to deal with this problem. The second maxim of Descartes' Discours de la Methode was "to break down every problem into as many separate simple elements as might be possible." This, similarly formulated by Galileo as the "resolutive" method, was the conceptual "paradigm" of science from its foundation to modern laboratory work: that is, to resolve and reduce complex phenomena into elementary parts and processes."

Whilst highly effective, the 'machine' model stands in conflict with the Aristotelian idea of synergy, later articulated as 'emergence', inherent within systems. Whilst we can develop an understanding of a system through detailed analysis of its parts, its 'emergent properties', its expression when these parts come together, can only really be understood in terms of the 'whole'.

In considering systems approaches within agriculture, Bawden, (1991) distinguishes between two types of systems inquiry - 'ontosystemic' which is concerned with the study of things as they exist in the world and 'episystemic' inquiry, which is concerned not with an external reality, but with "*peoples perceptions of reality"*. Bawden goes on the state that Farming Systems research is an example of the former, whilst Checklands (1981) Soft Systems Methodology is an example of the later. Von Bertalanffy, (1972) labels this 'system philosophy, and identifies systems ontology and epistemology along similar lines to Bawden, and adds the idea of systems values. His 'systems ontology' concerns itself with the distinction, or lack thereof, between 'real' and 'conceptual' systems and how such distinctions can be made. His 'systems epistemology' emphasises how 'reality', 'truth' and 'knowledge' are *"an interaction between knower and known, and thus dependent on a multiplicity of factors of a biological, psychological, cultural, and linguistic nature."* Von Bertalanffy (ibid) contrasts his systems philosophy with systems technology and systems science, which is akin to Checkland's (1985) hard and soft systems distinction. The hard/soft systems divide has several analogues in the social sciences. Habermas(1984), in critiquing the nature of western society and its dominance by positivist science, divides human action into two main types – purposive/rational and communicative action. Mingers, (1980) highlights that such a distinction is;

"similar in spirit to previous sociological categorisations such as Gemeinschaft/ Gesellschaft (Tonnies), informal/formal (Mayo, Homans) and traditional/bureaucratic authority (Weber)." (pg 41).

Such categorisations are viewed by Greeley (2002) as being part of the great sociological story which attempts to describe and explain the massive social transition of the enlightenment and industrial revolution(s). They speak, somewhat romantically, of a progression from traditional, familial, agrarian social roots to more formal, structured and machine based ways of working and relating. This progression is often seen as not one of choice by the masses, rather one of disruption and disturbance. There is always an air of longing for one world over the other and a concern for the plight of society as it lurches toward the unknown. Implicit – sometimes explicit - within all of these categorisations are a view of what is right, rational, practical and useful, what could be, should be or might be if we, as society, were to organize ourselves in one way versus another (Gray, 1964; Swidler, 1973; Victor and Stephens, 1994).

These distinctions point to different views on what the world is, how it can be known, what it means to act in the world, and how our action may influence the future. They can therefore be understood as different worldviews. The term 'worldview' or 'Weltanschauung' has been variously described as *"a comprehensive conception or apprehension of the world especially from a specific standpoint"* (Miriam Webster), *"an intellectual construction which gives a unified solution of all the problems of our existence in virtue of a comprehensive hypothesis, a construction, therefore, in which no question is left open and in which everything in which we are interested finds a place."* (Freud, 1936), and *"a coherent collection of concepts and theorems that must allow us to construct a global image of the world, and in this way to understand as many elements of our experience as possible."* (Aerts *et al.*, 1994).

Worldviews are akin to Schon and Rein's (1994) 'generative metaphors'. These are grand stories which carry over from context to context and enable the familiar and unfamiliar to be seen in new ways. These stories have a deep psychology and are ground in not only value and belief systems, but images and cultural forces that have stood the test of time. Schon and Rein (ibid) go on to suggest that it is the way in which individuals, organisations and institutions 'name and frame' problem situations via such metaphors which sows the seed of conflict in complex problem domains.

The importance of ontology, worldviews and generative frames to agriculture and innovation relate to their role in framing problem contexts and articulating what action to make progress in such context may be. How a problem is framed dictates how it is understood and therefore what constitutes action to make progress. If the problem of live export of sheep is viewed as a violation of animal rights, the only viable solution is the cessation of the trade. If however the problem is viewed as a failure within an ethical trade associated with international food security, a very different solution is imagined. So whilst actors within the Australian AIS may agree that systems approaches are necessary to address contemporary challenges, the underlying 'worldviews' upon which such a view is based may not be aligned and therefore may be the root of conflict, confusion and a mismatch of 'means' to 'ends'. In fact, agreement around 'ends' becomes problematic due to divergence within the constitutive elements of worldviews. In the next section we explore how worldviews, frames and ontologies can be linked with institutional theory to progress a framework for exploring the 'fundamental' forces shaping innovation in Australian agriculture.

Institutional Logics and organising for innovation.

Fundamental factors - the policy environment, formal and informal institutional rules of the game and the orientation of society toward change - are not really 'fundamental' at all, rather they are informed and shaped by further underlying forces. Social theory would suggest that policies, institutions and societal orientations within a domain form part of a 'socio-technical regime' which:

"……..*forms the 'deep structure' that accounts for the stability of an existing socio-technical system. It refers to the semi-coherent set of rules that orient and coordinate the activities of the social groups that reproduce the various elements of socio-technical systems*"(Geels, 2011a)

In the context of innovation and change, socio-technical regimes can be understood as an element of a "Multi Level Perspective" (MLP) on social transition:

"The MLP distinguishes three analytical levels: niches (the locus for radical innovations), socio-technical regimes, which are locked in and stabilized on several dimensions, and an exogenous socio-technical landscape. These 'levels' refer to heterogeneous configurations of increasing stability. The MLP proposes that transitions, which are defined as regime shifts, come about through interacting processes within and between these levels." (Geels, 2011b).

Change in the key elements underpinning productivity growth as defined by the productivity commission therefore could be seen as the outcome of transitions and alignments between these 'multiple levels' (Geels and Schot, 2007). This provides a starting point for exploring how such forces and factors may be influenced to enhance innovation. Fuenfschilling and Truffer, (2014) suggest that these levels can be understood as different degrees of structuration. Structuration theory holds:

"……that structure does not exist outside the actions of agents; rather it is the outcome of repeated actions by multiple actors. For example, authoritative management can be practised only as long as both employers and employees adhere to this routine. Once people start to ignore this routine, or start acting differently, the structure that once sustained this precarious work practice ceases to exist. This two-directional reinforcing process is called the 'duality of structure' reflecting the idea that the structure that drives the behaviour of agents only exists because agents act according to the structure." (Kroon and Paauwe, 2014a)

This 'duality of structure' (Giddens, 1984) would seem to describe well the nature of innovation in agriculture at the moment. On the one hand there exists a range of complex, multifactorial problems such as water policy and management, labour availability and capability, social licence around precarious natural resources and animal welfare, and managing the impacts of a variable climate, yet on the other hand you have a 'research, development and extension system' which, based on its self description, still adheres to a science centric, liner model of innovation. According to structuration theory, this model persists, largely due to the continued routines of agents within the structure which perpetuates it. These routines are informed by an underlying logic, likely unconscious and somewhat disconnected from the complexity of problems facing agriculture. Many authors (Thornton and Ocasio, 1999; Fuenfschilling and Truffer, 2014; Dahlmann and Grosvold, 2017; Mutch, 2018; Waeger and Weber, 2019) identify these 'institutional logics' as being both the core constituent of 'structures' and a key 'influencer' of routines within any given context. They are:

"The socially constructed, historical pattern of material practices, assumptions, values, beliefs, and rules by which individuals produce and reproduce their material subsistence, organize time and space, and provide meaning to their social reality."(Thornton and Ocasio, 1999).

These logics can be seen as material and symbolic (Thornton and Ocasio, 1999), define the formal and informal rules of the game, shape values and guide interpretation and adjustment of action. The nature of human existence dictates that context and experience shapes how these overarching 'logics' get combined and reconfigured through practice.

"These ideal typical institutional sector logics get reconfigured and translated in organizational fields. Field logics emerge as a combination of one or more institutional sector logics. Since actors are assumed to be bounded in their rationality field logics are used as guiding principles that offer specific rationalities, set the rules of the game, allocate power and status and steer attention towards specific problems and solutions (Thornton and Ocasio, 2008). A change in field logic will lead to a change in actors' strategies, problem focus or technology." (Fuenfschilling and Truffer, 2014)

Agriculture can be seen as an organisational 'field' (Kroon and Paauwe, 2014b). Productivity and hence innovation, can therefore be seen as an expression of practice and performance within this field. Such practice is shaped and reinforced by institutional logics which in turn perpetuates the system. If productivity performance is poor, which under the logic outlined from the outset suggests our innovation capacity is poor, then there is a distinct possibility it is due to some limiting element within the logic(s) which underpins the organisational field of agriculture.

Exploring how institutional logics shape innovation performance in Australia – a conceptual framework

The purpose of our research is to progress an understanding of the nature and influence of institutional logics on Agricultural innovation in Australia, and contribute to the capacity of the AIS to enable 'institutional innovation'. A number of questions emerge from this which inform our research:

What institutional logics can be observed within the Australian Agricultural Innovation system?

Are particular institutional logics more effective at reproducing and sustaining innovation in agriculture?

How do institutional logics change?

Based on the above discussion we have developed a conceptual framework to direct exploration of these questions. Part one of this framework is described in figure 4. Structuration within the organisational field of agricultural research and development will be explored with the view to illicit a) the dominant logic 'in use' within Australian agricultural R&D, and b) competing logics which may be also evident. This will be done through analyzing the espoused 'logic' of innovation through analysis of relevant policy and investment documents within the field, along with developing understanding of the 'logic in use' via interviews to understand routines within the field. The aim is to use an understanding of innovation practice (espoused and in use) to describe the structural elements of innovation and through this inductively describe existing institutional logics. With regards to linking logics to innovation performance, the R&D systems of Australia and the Netherlands will be compared given their contrasting productivity performance.

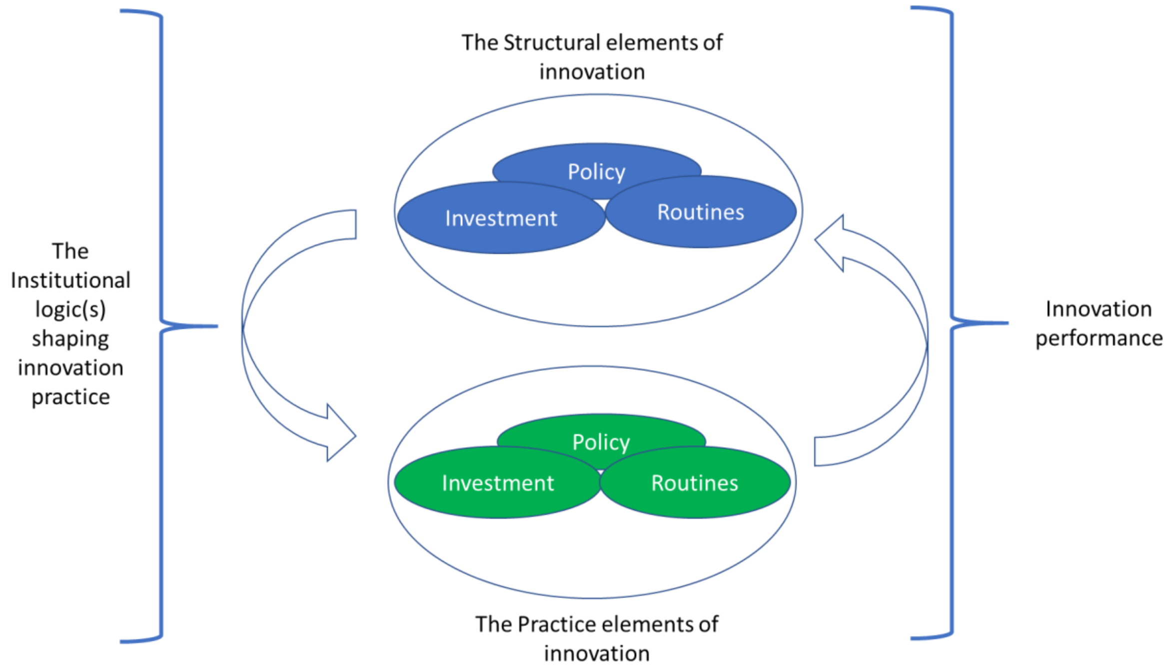


Figure 4: Conceptual framework for the exploration of institutional logics and their impact upon innovation practice and performance

Just identify logics alone however is not enough. Change in institutional logics and how this may be enabled therefore becomes of interest. Organisational fields such as agriculture are clearly diverse, with socio-technical regimes surviving presumably due to their relative 'fitness'. Fuenfschilling and Truffer, (2014) suggest that the overall structuration of a field is due to the relative strength of alternative field logics. *"At any moment, these logics may coexist, compete, contradict or complement each other and thereby reinforce or weaken the structuration of the field."*(Fuenfschilling and Truffer, ibid).

Institutional 'work' therefore emerges as a useful concept with regards to bringing about change within the prevailing/dominant logic inherent in an organisational field. Lawrence and Suddaby, (2006) define institutional work as *"purposive action of organizations and individuals aimed at creating, maintaining, and disrupting institutions" (pg 215)*. Such work is; "*concerned with how change happens through the agency of individuals who form part of, or are affected by, an institution."* (Dahlmann and Grosvold, 2017). Figure 5 sumarises part two of our conceptual framework guiding the exploration of institutional work as a mechanism for change in the dominant logic. Drawing on the MLP, institutional work can be viewed as a mechanism for competing, or 'niche' logics, to alter the prevailing logic within the field of agricultural R&D. We aim to use case studies to both describe the existence of institutional work in practice and articulate the key enablers and barriers to institutional work within the field of Australian agricultural R&D. Of interest is the role different actors in the AIS may play in this, particularly extension, given the key role brokering practices play in innovation.

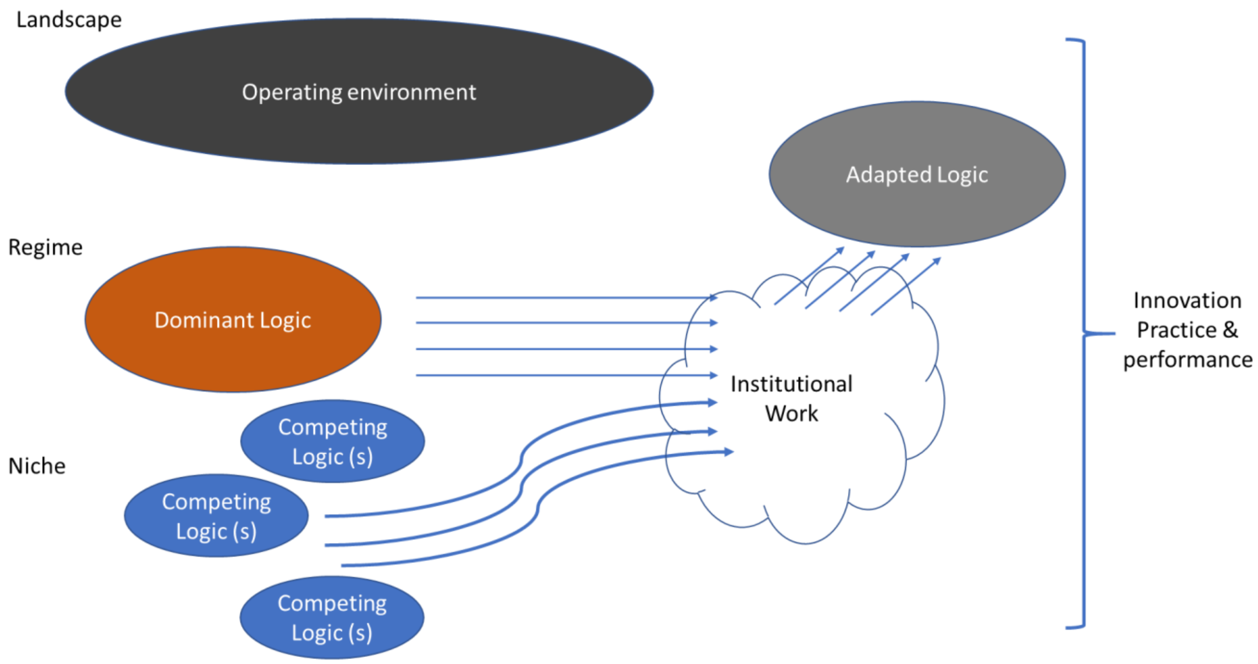


Figure 5: Conceptual framework for exploring institutional work using the MLP.

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UNRAVELLING SYSTEM FAILURES WITHIN EUROPEAN MULTI-ACTOR CO-INNOVATION PROJECTS IN AGRICULTURE: A COMPARATIVE ANALYSIS

Evelien Cronin[a], Sylvie Fosselle[b], Elke Rogge[c], Thomas Block[d]

[a] Institute for Agriculture and Fisheries Research (ILVO)
[b] Institute for Agriculture and Fisheries Research (ILVO)
[c] Institute for Agriculture and Fisheries Research (ILVO
[d] Ghent University, Department of Political Sciences, Centre for Sustainable Development

Abstract: European Union (EU) level funding programmes in support of research and innovation in agriculture such as Horizon 2020 and INTERREG, increasingly require prospective partnerships to bring together different types of actors in order to co-create knowledge and innovation. Although the multi-actor and geographical distribution requirements have created opportunities for new types of actors to participate in these EU-wide multi-actor co-innovation projects, a few pertinent questions point to areas of concern in the way these projects are currently being stimulated by the EU: What are the key challenges met during the project lifecycle? Who is involved in these projects, i.e. do they truly represent a diversity of actors, or rather a distinct set of established, dominant or specialised actors? What is the added value of working with different nationalities, does it allow for broad cross-fertilisation and diffusion of knowledge or is it merely a complex management challenge? How do these projects thus succeed in combining complementary expertise and in finding a balanced relevant representation in terms of Member States, sectors, stakeholders and governance levels? Even though these EU-wide multi-actor projects take up a significant amount of funding and are perceived to play a pertinent role in the transition to a more sustainable agrifood system, in-depth and comparative studies in search of answers to these questions are scarce. Furthermore, it requires a perspective which recognises not only the complexity of this type of co-innovation processes, but also the multi-level reality in which they take place. The Multi-level Innovation System (MINOS) framework enables such an analysis by defining the presence, influence and interdependence of multiple Innovation Systems (IS) in these projects at four levels; the European, the national, the project and the partner level. Applying this framework will allow us to identify different types of multi-level system failures influencing the performance of these projects, i.e. failures which are the result of the interaction and connection between different IS levels and which influence the occurrence and severity of system failures in other IS levels. We aim to analyse and compare the functioning of two European multi-actor projects: an H2020 project on solving drink water pollution from agricultural origin and an INTERREG North West Europe project on the reduction of food losses in the first part of the value chain. INTERREG projects have a more narrow geographical focus, are smaller in size and fit in more open calls for proposals than the H2020 projects. Useful lessons on how to improve co-innovation processes in multi-actor projects can be learnt from both policy frameworks. For both practitioners and policy-makers alike, it would be beneficial to improve understanding on how these projects accommodate differences in institutional, infrastructural, cultural and social contexts.

DETERMINANTS OF SUCCESS IN THE MULTI-LEVEL IMPLEMENTATION OF THE MULTI-ACTOR APPROACH TO INNOVATION IN AGRICULTURE, FORESTRY AND RURAL DEVELOPMENT: AN ANALYTICAL FRAMEWORK

Jekaterina Markow[a], Susanne von Münchhausen[b], Anna Maria Häring[c]

[a] Hochschule für Nachhaltige Entwicklung Eberswalde
[b] Hochschule für Nachhaltige Entwicklung Eberswalde
[c] Hochschule für Nachhaltige Entwicklung Eberswalde

Abstract

The Multi-Actor Approach (MAA) is a normative standard the European Commission (EC) formally applies to many of its (co-)funded innovative projects in agriculture, forestry and rural development. The MAA requires projects 1. to build on the activities of partners with complementary types of knowledge, including in particular (representatives of) the targeted users of the project results; and 2. to ensure the joint engagement of these diverse partners in all phases of the innovation process.

Projects that are required to comply with the MAA are officially called 'Multi-Actor projects'. They include some international research and innovation projects funded under the EC's Framework Programme for Research and Technological Development Horizon Europe (or its predecessor Horizon 2020), as well as local EIP Agri Operational Groups (OGs), which are co-funded by the EC and the Member States (MS).

As with all public policies, several groups of actors – including the EC itself – have a legitimate interest in learning how well the MAA is being implemented by its intended target actors. A general answer to this question is complicated by the fact that Multi-Actor projects differ in many respects, such as the innovative objectives they pursue, the size and composition of their consortia, the duration of their activity, and their geographic scope. One aspect that makes it particularly difficult to identify general implementation determinants is their embeddedness in distinct multi-level governance settings. For example, while Horizon Europe-funded research project consortia operate under the direct management of the EC's agencies, OGs are funded under a measure which is formulated by the EC but implemented at the national, or in some MS, regional level. These differences inevitably have an impact on how success in the implementation of the MAA can be achieved.

In this paper, we propose a framework for analysing the factors that determine success in the implementation of the MAA, as well as their interrelations. This framework builds on a review and integration of insights from various fields of social scientific research, notably research on public policy implementation, multi-level governance, and participatory approaches in agricultural policy. To test the framework, we apply it to data from four case studies of OGs that we conducted in 2020 in the frame of the H2020-funded research project LIAISON.

1. Introduction

The Multi-Actor Approach (MAA) is a normative standard the European Commission (EC) formally applies to many of its (co-)funded innovative projects in agriculture, forestry and rural development. These projects are officially called 'Multi-Actor projects' (MA projects) (cf. EIP Agri 2017). They notably include all projects that form part of the *European Innovation Partnership for Agricultural Productivity and Sustainability* (EIP Agri) such as some international research and innovation projects funded under the EC's Framework Programme for Research and Technological Development *Horizon Europe* (or its predecessor *Horizon 2020*), as well as local *EIP Agri Operational Groups* (OGs), which are co-funded by the EC and the Member States (MS). However, other EU funding programmes such as LIFE, Interreg or LEADER/CLLD apply similar approaches.

A review of relevant policy documents reveals that the EC does not currently offer a consistent definition of what the MAA actually requires of the project consortia to which it applies. Requirements vary for different types of MA projects and typically also individual projects. However, the MAA – in any of its specifications – entails *at least* the following normative elements:

1. It requires innovation projects to build on the activities of "partners with complementary types of knowledge – scientific, practical and other" (EIP Agri 2017: 1), including in particular (representatives of) the targeted users of the project results (multi-actor requirement); and
2. to ensure the joint engagement of these diverse partners in all phases of the innovation process, "from participation in the planning of the project and experiments, to implementation, the dissemination of results and a possible demonstration phase." (EC 2020) (interactive innovation requirement).

As with all public policies, several groups of actors – including the EC itself – have a legitimate interest in learning how well the MAA is being implemented by its target actors. Presupposing that 'success' in the implementation of the MAA means compliance with the above requirements – how well are MA consortia faring, and which factors determine implementation success? In this paper, we will leave aside the first of these questions – that of assessing actual MAA implementation *performance* – and focus on the second: that of performance *determinants*.

A general answer to this question is complicated by the fact that MA projects differ in many respects, such as the innovative objectives they pursue, the size and composition of their consortia, the duration of their activity, and their geographic scope (cf. Fieldsend et al. 2020). One aspect that makes it particularly difficult to identify general implementation determinants is their embeddedness in distinct *multi-level governance* settings (cf. Hooghe/Marks 2003). For example, while *Horizon Europe*-funded research project consortia operate under the direct management of the EC's agencies, OGs are funded under a measure which is formulated by the EC but whose implementation is managed by authorities at the national or, in some MS, regional level. These differences inevitably have an impact on how success in the implementation of the MAA can be achieved. How can such heterogeneous cases be compared in terms of the factors that determine implementation performance?

In this paper, we propose a framework for analysing such factors as well as their interrelations. This framework builds on a review and integration of insights from various fields of social scientific research, notably on public policy implementation, multi-level governance, and participatory approaches in agricultural policy. To test the framework, we will apply it to data from four case studies of OGs that we conducted in 2020 in the frame of the H2020-funded research project LIAISON (cf. Cronin et al. 2021). OGs are a particularly challenging study object because they are co-funded from the European Agricultural Fund for Rural Development (EAFRD) and the national or, in some MS, regional Rural Development Programmes (RDPs) and are being managed by national or regional public bodies within the legal scope defined by the EAFRD regulation. This means that more levels of governance are involved in OG implementation than in other MA partnerships, especially consortia funded by the EU research fund Horizon Europe or its predecessor H2020. Furthermore, MS/regions implement the OG measure differently through their RDPs. For example, while several MS have designated an innovation support service provider (ISS) to assist the OG with application or problems during project implementation, not all have done so, and the structure and function of the ISS differs from MS/region to MS/region.

In the next section, we will describe the theoretical background of our framework and define its key variables (2). We then present the main findings from applying this framework to the four OG case studies (3). The article concludes with a discussion of the empirical findings and the framework's benefits and limitations (4).

2. Theoretical background and key variables of the analytical framework

In this section, we define the dependent variable (2.1) and independent variables (2.2) of our framework, together with a visualisation (graph 1). (Numbers in square brackets refer to the respective numbered elements in the graph.)

2.1 Dependent variable: Implementation performance

The core concept of our framework is that of 'implementation'. Implementation means the act of realizing a goal [1] – understood as formulation of a desired state of the world – defined by a public policy (cf. O'Toole 2000). While 'implementation' in this sense can both refer to a single actor's activities or the activities of diverse actors at once, our framework focuses on the implementation performance of a single (individual or collective) actor, or actor *type*.

For each policy goal, we assume there exist (in reality or hypothetically) *objectives* which identify the activities that are needed to achieve the policy goals (cf. Aragrande/Argenti 2001). By thus translating goals into concrete mandates that can be attributed to actors, objectives effectively provide the *success criteria* against which to measure actors' implementation performance.

By *'implementation performance'* we mean the extent to which an actor actually manages to comply with the particular objective(s) the policy maker expects him/her to comply with. Accordingly, we consider an actor's implementation performance successful to the extent that s/he complies with the objectives he/she is expected to comply with, and unsuccessful to the degree that s/he does not.

2.2 Independent variables

There is a broad consensus among researchers that implementation performance depends both on the characteristics of the implementing actor and various external factors, i.e. factors beyond the implementer's control (cf. Mazmanian/ Sabatier 1989; Velten/Jager/Newig 2021). As one observer of the field noted as early as 1986, empirical studies of policy implementation as well as conceptual contributions have identified over 300 such potential determinants of implementation performance (cf. O'Toole 1986; cf. Saetren 2014). Our framework represents an attempt to integrate most of these findings into one coherent analytical approach. It is based on the premises that (1) an actor's implementation performance is a function of his or her *ability to implement* and that (2) this ability is determined to varying, case-specific degrees by the *implementation context*.

2.2.1 Ability to implement

By an actor's ability to implement we mean all the *features of an implementing actor that determine the likelihood of his or her implementation success.* We focus here on those actor features that either make implementation success more likely ('assets'), or less likely ('deficits'), compared to a hypothetical state in which those features are not present and in which all other determinants permit implementation success. While assets constitute a *success factor*, 'deficits' constitute an implementation *bottleneck*.

We propose that all of an implementing actor's assets and deficits fall into *six* categories [2]. The relevance of each of these categories for implementation performance and, within each category, the extent and direction of influence of each determinant, will vary across empirical cases.

Three such categories of determinants are largely uncontroversial. Researchers of various disciplines agree that an actor's ability to achieve certain goals depends on (a) his or her possession of material *resources* needed for implementation, such as budget, facilities and time; (b) his or her possession of relevant *capacities*; and (c) his or her *motivation* to perform the activities needed for goal achievement (cf. e.g. Mazmanian/Sabatier 1989). Within each of these categories, an actor may feature multiple assets and/or deficits. Which of his or her features may become assets or deficits for implementation depends, among else, on the goal being implemented. For instance, not all goals require the same kinds of resources or capacities to be achieved.

Furthermore, a major interest of practitioners and researchers of policy implementation concerns the *normative coherence* of implementation, i.e., whether implementation is compatible with certain other norms at a higher or at the same regulatory level (cf. Fischer-Lescano/Teubner 2004). We integrate this concern into our framework by assuming that most policies are associated with a *claim to legitimacy*. While 'legitimacy' can refer to a policy's compatibility with legal as well as ethical or social norms, the focus of our framework is on *legal* compatibility, i.e. *legality*. We further assume that policy implementation may only be considered successful to the degree that it preserves the *policy's legitimacy basis*, i.e., does not violate other legal norms that the policy claims to be compatible with. Accordingly, another feature that matters for an implementer's performance is (d) which *legal resources* s/he possesses for goal implementation; referring to both the rights and duties that arise for the implementer from the policy itself and from other legal norms the policy claims to be compatible with. While some rights and duties provide the implementing actor both with *incentives* and *options* to implement the policy objectives ('assets'), others may create negative incentives or legal hurdles ('deficit').

But even where an implementer possesses appropriate legal resources for implementation, s/he may not always be fully aware of these resources, i.e. of what s/he can and cannot legally do to implement the objectives (cf. Wagner 2009). Since one arguably cannot intentionally observe duties or make use of rights that of which one is unaware, an actor's degree of (e) *certainty about his or her legal resources for implementation* is likely to affect his or her implementation performance as well.

Finally, research has shown that the ability of a collective to achieve certain goals is highly dependent on the ability of its individual *members* to contribute to collective performance (cf. Collective Action, Ostrom 2009). We propose that this has two implications for policy implementation when the implementer is a collective. First, it means that implementation performance does not only depend on how well the *collective* fares with regard to the above categories of factors (a-e). Rather, performance is also influenced by whether the *individual* *members* possess all they need to contribute to the collective's performance. Secondly, this dependence of the collective on its individual members also means that the collective's performance will be determined by (f) the *quality of collaboration* between members, e.g. whether they have established appropriate mechanisms for decision-making, knowledge sharing, and conflict resolution (cf. e.g. Stokes Berry/Berry/Foster 1998).

Overall, then, our framework considers an actor's ability to implement a certain policy to be comprised of six categories of factors or features:

1. the *rights and obligations* the actor possesses (category of 'right')
2. the extent he is *aware of these rights and obligations* ('knowledge of right')
3. the *resources* he possesses to make optimal use of his or her legal leeway for implementation ('resources')
4. the *capacities* s/he possesses to make optimal use of these rights and resources for implementation ('capacity')
5. the *motivational resources* s/he possesses to make optimal use of those rights, resources, and capacities for implementation ('motivation')
6. and the *mechanisms for collaboration* the actor has established internally ('quality of collaboration')

Based on the above considerations, we assume that in collective actors, the first five of these categories apply both to the collective as a whole, *and* to its individual members. In addition, the sixth category only applies to collective implementers, not individuals.

Determinants of implementation performance may interact with each other both within and across categories in various ways, e.g. strengthen or weaken each other's effects or jointly contribute to or result in a third factor [3].[19] With this assumption, we account for the fact that the features that comprise an actor's ability to achieve goals are neither causally independent from each other, nor static, but that, very often, assets and deficits accumulate. Including this assumption also invites thinking about how implementing actors may build on their assets to compensate for some of their deficits.

2.2.2 Implementation context

An actor's ability to implement a policy is always influenced to some extent by determinants s/he may not affect (cf. Mazmanian/ Sabatier 1989; Velten/Jager/Newig 2021). These factors comprise his or her *implementation context*. We assume that some features of this context can *strengthen* the actor's ability to implement, i.e., constitute *success factors* of implementation performance, while others can *weaken* it and thus constitute *bottlenecks*. Since these factors become effective more 'upstream' in the implementation flow, we propose to call them 'upstream bottlenecks' respectively 'upstream success factors'.

We distinguish between two types of such factors: 1. the activities of actors at higher governance levels, and 2. the wider environment, which consists of activities of informal governance actors as well as aggregate features of the implementation context.

[19] An exception from this assumption is the implementer's possession of rights, which our framework assumes will be solely determined by his or her implementation context.

2.2.2.1 Actors at higher governance levels

As mentioned above, our framework takes into account that most policies, including the MAA, are implemented in multi-level governance settings (cf. Hooghe/Marks 2003; Börzel 2020; Jeffery/Peterson 2020) [4]. Analysing the implementation of policies as embedded in multi-level governance settings means recognizing that the ability of an actor to implement a specific policy will partly be determined by other actors who have authority over him/her, i.e., have a *formal right* to condition his or her ability for implementation (governance actors).

Governance actors operate at different levels in that they have different *degrees* of decision-making power relative to one another with regard to the policy goal being implemented. Accordingly, we call an actor an ‚actor at a higher governance level' who may define implementation conditions which other governance actors may either only specify further or implement, but not alter or override. In this view, the 'implementing actor' occupies the lowest governance level, for s/he has, relative to all other actors, the least governance options (even though s/he may have some discretion in his or her implementation of the policy goal). Our framework also acknowledges that multiple actors may operate at the same governance level and may employ some form of division of labour.

Governance actors need not be governments or public agencies (cf. Börzel 2020). In fact, many current EU policies require the involvement of a broad range of societal actors in their implementation and monitoring (cf. Newig/Koontz 2014). In our framework, the sole criterion for defining an actor as a relevant governance actor is therefore whether that actor has, in relation to the policy that is being implemented, a formal *right to intervene in the implementation process at any stage.*

Actors at higher governance levels may either affect an implementing actor's performance directly by positively or negatively affecting one or more of the six categories of factors that comprise his/her *ability to implement*, especially his/her possession of rights and duties. However, they may also affect his/her performance indirectly, namely by affecting the *activities of actors at lower governance levels* (who in turn affect his/her ability to implement) or by affecting his/her *environment*.

Feedback from governance actors at lower governance levels – including from the level of implementation – to actors at higher governance levels or at the same governance level may also impact implementation performance indirectly (cf. Moynihan/Soss 2014) [5]. By feedback we mean any type of activity by actors at lower governance levels that has the potential to alter the activities of actors at higher governance levels.[20] Importantly, our framework does not consider activities here that lead to *reformulations* of the very policy objectives being implemented, but only activities that change *implementation* (cf. section 4).

[20] The difference between governance and feedback activities is that while both may lead to alterations in the activities of the actors at which they are directed, they exert a different degree of *pressure to comply*. The fact that policies are formulated at a higher governance level means per definition that all actors who occupy lower governance levels in the implementation process are legally obliged to comply. In contrast, it is not mandatory for actors at higher governance levels to comply with feedback from lower-level governance actors; rather, they may do so if they consider it prudential. For a similar argument, cf. Mazmanian/Sabatier 1989.

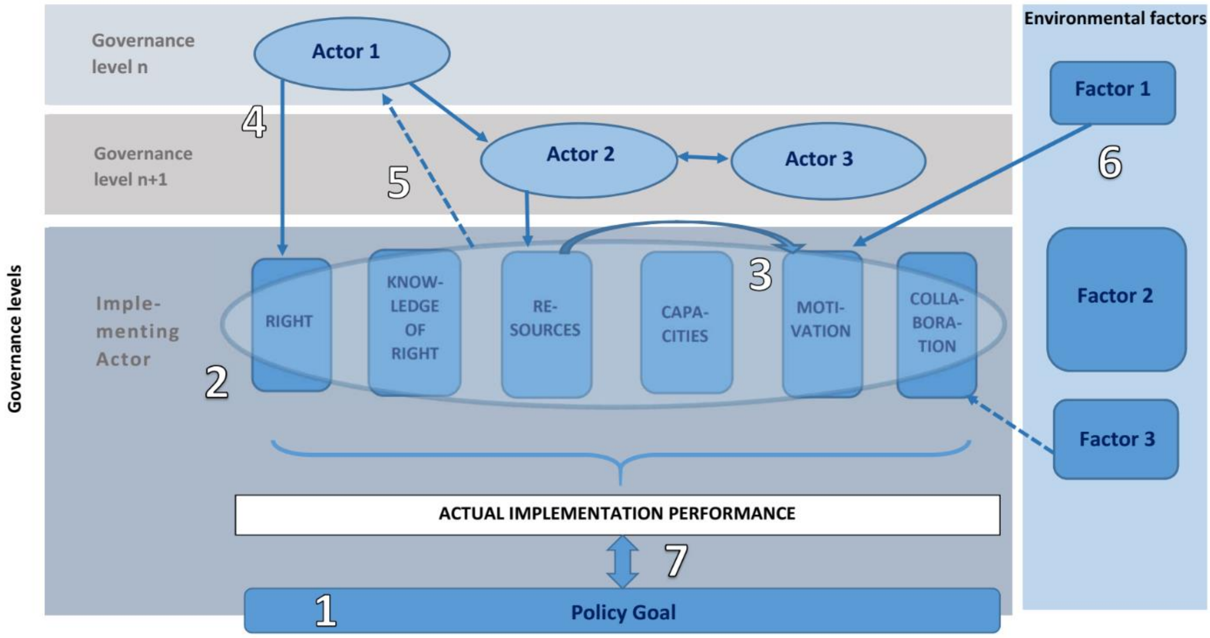
2.2.2.2 Environment

Next to governance actors, a variety of determinants not anticipated in and regulated by the formal implementation procedure are decisive for the outcome of most implementation processes (cf. O'Toole 1986; 2000). In our framework, we use the term 'environment' as a catch-all denomination for such determinants [6]. This category contains, in turn, two groups of factors: the activities of actors without formal decision-making power in the process, such as informal interest groups (cf. Cahn 2013), and aggregate features of the implementation context such as ecological, demographic and socio-economic conditions as well as policies from other policy areas. Considering the diversity of cases of policy implementation, our framework refrains from precluding which environmental factors will actually be relevant for explaining implementation performance in a particular case. Rather, the analyst must make informed decisions about which environmental factors to include in the analysis.

Like governance actors, informal governance actors and environmental factors may be ranked according to the level of influence they have over each other. According to this logic, features of the global economy are more likely to affect social and economic conditions in a particular area or sector than vice versa. Ranking environmental factors in this way will help to explain also the kind of influence they each have on implementation performance, and why they may effect certain stages in this process, but not others. Like between governance actors, feedback may occur from less influential environmental factors to more influential ones.

Our framework also assumes that environmental factors interact with the activities of governance actors, and that feedback takes place both from environmental factors to governance actors and *vice versa*. For instance, global markets (environment) respond to the activities of governance actors, and governance actors respond to markets.

Conceptualising an actor's implementation performance thus as a function of his or her ability to implement, which is in turn at least partly shaped by actors at higher governance levels, the implementation context, and feedback mechanisms between these determinants, allows to identify the *causal pathways* that resulted in a particular performance. Determining such causal pathways of implementation success respectively failure is precisely the aim of our framework [7].



Graph 1: Visualisation of the analytical framework for multi-level policy implementation

3. Determinants of success in the implementation of the Multi-Actor Approach by Operational Groups: Results from four case studies

In this section, we present selected findings from applying the above framework to case studies of four OGs conducted in summer 2020 in the context of the EU research and innovation project LIAISON (2018-2022). The selected OGs were located in different countries (France, Germany, Italy and Poland) and addressed different issues (local introduction of hemp production, reintroduction of two ancient grains, establishment of a laboratory for local producers' shared use, participatory development of area-specific action plans). The collection of data was based on desk studies of relevant documents and interviews (partly face-to-face, partly online) with OG coordinators and various members as well as key stakeholders, e.g. from the managing and granting authority or business partners. Data collection followed an agreed guideline and was documented in a standardised 'case study reporting template' which was reviewed internally to ensure the comparability of data (cf. Cronin et al. 2021; Fieldsend et al. 2020).

Our case studies show that OG members generally approve of the concept of the funding scheme, which offers beneficiaries' of up to 100% funding for the *attempt* to innovate, rather than making funding conditional on a particular *outcome* such as an increase in productivity. Beneficiaries did not object to the amount of funding granted, which suggests that the activities they implemented matched the awarded amount. However, some interviewees also mentioned that they applied for funding from additional sources to implement some of their activities.

However, there are major bottlenecks in the implementation of MAA by OG. First, practitioners such as farmers or foresters generally have fewer resources and capacity to participate in OGs or in specific OG activities compared to other actors. Reporting requirements impose a particularly heavy administrative burden on small (family) businesses, who often lack administrative capacity and time.

Secondly, differential economic stakes of OG members have a major impact on their cooperation. While the project funding is the main or a major source of income for some partners, it is only an additional support for partners whose main income comes from other sources such as business activities or employment. OG partners of the latter type typically have relatively lower economic stakes in the project results and therefore less incentives to 1. follow the requirements of the Grant Agreement in case of a (perceived) collision with the necessities of their main income-generating activity; 2. invest time in project activities or engage in stakeholder activities that yield no economic benefit; and 3. disseminate marketable findings/innovative solutions (risk of losing market advantage). In contrast, similar economic stakes in the project and trust through previous collaboration appeared to be motivational success factors for good internal collaboration.

The *implementation context* influences OGs' ability to implement the MAA in several important ways.

The inflexibility of the OGs' Grant Agreement with the *national/regional granting authorities* and (in two cases) the *paying agencies'* perceived rigidity in implementing them add to the administrative burden of beneficiaries and, sometimes, financial cost. Our case studies also reflect that *beneficiaries' rights differ considerably across MS*. In some MSs or regions, the OG measure is designed more favourably than in others, offering beneficiaries a comparatively higher maximum amount and a longer funding period, as well as a lower rejection rate and access to innovation support services (ISS). In addition, ISS differ in their design. In some regions/MS, ISS lack rights (limited remit), resources (understaffing) or capacity.

Legal collisions between funding requirements and national/regional laws or procedures (e.g., administrative provisions about funding rates for staff; different budget periods) often lead to legal obstacles or increase the administrative burden. For example, although in principle OGs can apply for investment funds from EAFRD under privileged conditions, the requirements (e.g. the obligation to use acquired machinery for the same purpose for several years, even after the end of the eligibility period) make it more attractive for OGs to pursue other investment funding options. These legal conflicts and shortcomings were insufficiently considered in EAFRD programming at the time of the case study analysis.

The *interplay of the governance actors involved* also has the potential to greatly influence MAA implementation and the implementation of OGs in general. Notable success factors include good collaboration between funding authorities; their adjustment of the funding measure based on beneficiaries' feedback – which in turn requires the existence of good feedback mechanisms between OGs and the funding authorities, as well as funding authorities' willingness and capacity to actually improve the measure's design; and their lenience towards beneficiaries in administrative matters.

Apart from differences in MS' implementation of the OG measure, the *overall support by the social and policy environment also varies among MS*, which also influences implementation performance. Notable bottlenecks include a weak Agricultural Knowledge and Information Systems (AKIS) and funding authorities' unfair privileging of certain actors as well as funding authorities' lack of resources, capacities and/or motivation to improve programming of the measure. In contrast, a strong national, regional or sectoral AKIS; a favourable market situation; good cooperation of local/regional/national public authorities with funding authorities; and the availability of additional funding sources on which OGs can constitute supportive environmental factors.

We further found that the *local context* is an important determinant of OGs' success in implementing the MAA. First, some of the studied OGs exhibited a strong local embeddedness. This improved their access to resources such as local informal support networks, which in turn provided missing resources (e.g. facilities) and capacities (e.g. in administration). Secondly, our case studies indicate that spatial proximity of partners enhances their motivation to collaborate. Conversely, cooperation in OGs has long-term benefits for partners that can last even beyond their joint activities, which also increase their motivation to participate. Notable benefits include better networks and trust building, as well as capacity building (professional skills, experience with project participation).

4. Discussion

4.1 Empirical findings

The empirical findings confirm that successful multi-actor collaboration in agriculture, forestry and rural development depends both on internal features of the respective partnerships, and environmental factors (cf. Velten et al. 2021) such as the state of the national or regional AKIS and the availability of additional funding sources to supplement OG funding. While the small sample does not allow to generalise findings, some of them, such as observed legal collisions between the OG measure and other EU or national laws, are clearly relevant for OGs and their implementation of the MAA in general.

One decisive *internal* factor that determines OGs' performance in implementing the MAA is how they manage their internal differences, especially with regard to the *economic stakes* their members have in their joint project. Different economic stakes mean that members have different – and differently strong – motivations to participate in OGs and to engage with others in activities (cf. Molina et al. 2021). Failure of (prospective) OG members to address such differences early on is therefore bound to lead, first, to a low participation of partners with lower economic stakes, which tend to be farmers, and secondly, to suboptimal collective performance and partners' frustration.

A particularly important *contextual* determinant of OGs' performance in implementing the two objectives of the MAA is the *multi-level governance* of the OG measure, which allows MS to implement the measure *differently*. As is typically the case with 'differentiated integration' in the EU (cf. Leuffen/Rittberger/Schimmelpfennig 2012), the implementation choices MS make here clearly do not only reflect their governments' legitimate priorities, but also their differences in resource and capacities. If national funding authorities lack budget, staff, or understanding of the measure or the MAA, they are unlikely to improve their implementation of the measure. This can reproduce existing power differences between MS, in that MS that already possess sufficient resources and capacities are likely to reap more benefits from the measure than those MS that lack these resources and capacities. The unequal relation of costs to benefits of implementation is also likely to make some countries more willing to implement the measure than others.

4.2 Reflections on the framework's benefits and limitations

Next to yielding empirical insights into the determinants of the implementation of the MAA by OGs, our case study analysis also shows the benefits of our framework. Firstly, the framework is able to cover simultaneously a variety of factors that affect OGs' implementation performance, as well as their causal interrelationships. This is certainly required if one wants to explain MAA implementation outcomes in contexts that involve not only multiple governance levels but also a great room for discretion of governance actors at lower levels. In doing so, our framework enables an assessment of implementation bottlenecks and success factors *across* OGs, despite their embeddedness in considerably different policy and social environments.

The framework may also serve as a starting point for the conceptualisation of various more specific explanatory approaches, as its concepts invite further theoretical elaboration. For instance, an in-depth analysis of the role of motivational resources in explaining implementation performance may operate with a more fine-grained concept of 'motivation' that distinguishes between different types of motivational resources, and otherwise adopt the general concepts proposed by the framework. Likewise, one may apply a particular analytical distinction of different modes of horizontal cooperation between governance actors in order to gain a more differentiated understanding of how such cooperation may affect policy implementation performance.

Moreover, the framework has the potential to bridge a gap between approaches to implementation which consider successful implementation an act of *compliance* with predefined goals, and approaches that focus on how implementers *redefine* policies and/or adapt them to their specific contexts (cf. Mazmanian/Sabatier 1989). From the first strand of theories, our framework adopts the understanding of implementation success as 'compliance'. While policies are always intermediate products of an ongoing cycle of formulation, implementation and reformulation, we propose that at some point in any policy process we also have an interest in measuring societal progress towards agreed policy goals and holding implementers accountable. At the same time, our understanding of policy goals is sufficiently broad to allow for policies that, rather than prescribing a particular course of action, only define some *minimal criteria* for implementers to meet. This definition anticipates that many policies – including the MAA – allow for implementers' discretion. By considering feedback mechanisms an independent variable, our framework also accounts for recursive implementation practices that involve specifications – albeit not actual *revisions* – of the initial policy goal.

Finally, we also found that by highlighting the multi-variate causes of implementation performance, the framework helps to identify multiple intervention options for optimising implementation. For instance, by reflecting that some of the current failures of OGs to implement the MAA requirements result from an interplay of the measure's design and socio-economic features of the different implementing MS and regions, the framework helps to see that implementation performance may be either improved by altering the measure's design, MS' socio-economic features, or both.

However, the framework also faces several shortcomings. For one, as much of current work in implementation research, it is so far purely suitable for qualitative, not quantitative analysis of implementation performance. While it helps to determine some of the factors that contribute to a particular implementation outcome, as well as the direction of that influence, it does not allow for an assessment of the actual *strength* of these influences. It would be worthwhile to see how the framework could be adapted to suit quantitative research purposes also.

Although the generality of the framework's assumptions is partly a strength, some assumptions could profit from further clarification. For example, it might be useful to include a more precise understanding of the interrelationships between variables, such as the distinction between moderating and mediating variables (cf. Baron/Kenny 1986). Other assumptions of the framework, on the other hand, may be more ontologically challenging than has been assumed here. For example, one may wonder whether focusing on the activities of actors with a formal right to participate in an implementation process does not overstate their influence compared to informal actors. Thus, Schakel (2020: 767) observes that there is a “significant sharing of authority between governmental actors within and beyond national states even in cases where the formal right to make a decision lies with national governments or the EU legislator“. Further testing of the conceptual framework on a variety of empirical cases of multi-level policy implementation will help to better identify key areas for its use and further improvement.

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CONTRIBUTIONS OF PARTICIPATORILY DESIGNED ORGANIC RESOURCE MANAGEMENT TECHNIQUES TO THE IMPROVEMENT OF SOIL FERTILITY IN AFRICA: EVIDENCE FROM KENYA, MALI, GHANA AND ZAMBIA

Fernando Sousa; Andreas Fliessbach, Noah Adamtey, Harun Cicek

Research Institute of Organic Agriculture. Department of Soil Sciences, Switzerland.

Abstract: Depletion of nutrients in smallholder farmers' soils that produce the major part of food is the main reason for food insecurity in many countries of Sub-Saharan Africa. Mineral fertilizers have been used in agricultural production systems in substantial quantities to improve crop yields. However, mineral fertilizer alone cannot increase and maintain soil fertility, particularly in tropical soils, where organic inputs allow for an increase in soil quality and fertility parameters. The ORM4Soil project has tested participatorily designed organic resource management techniques aiming at the improvement of soil fertility in Kenya, Mali, Zambia and Ghana. In Mali, agroforestry systems with *Gliricidia sepium* has been shown to have a positive effect on yields and soil fertility. In Ghana, local organic residues such as the palm oil empty fruit bunch have helped farmers improve the quality of their soils. In Kenya, the use of *Tithonia* has added organic matter to the soil and in Zambia, an improved version of a locally practiced green manure technique has proved advantageous to farmers.

ARE ADVISORS THE PRIMARY PROVIDERS OF INNOVATION SUPPORT SERVICES IN FORESTRY AND AGRICULTURE? PRELIMINARY FINDINGS FROM THE PROJECT LIAISON

Susanne von Münchhausen[a], Jekaterina Markow[b], Anna Häring[c], Evelien Cronien[d], Andrew Fieldsend[e]

[a] Hochschule für Nachhaltige Entwicklung Eberswalde
[b] Hochschule für Nachhaltige Entwicklung Eberswalde
[c] Hochschule für Nachhaltige Entwicklung Eberswalde
[d] Eigen Vermogen von het Instituut voor Landbouw en Visserijonderzoek
[e] Agrargazdasagi Kutato Intezet

1. Introduction

In recent years, notions such as 'innovation support services', 'innovation facilitation', and 'innovation brokerage' have become more and more commonplace in the field of agricultural innovation in many countries. While the use of these termini is not unified (cf. Ndah et al. 2018: 6f.), their overall emergence testifies to a *paradigm shift* in thinking about agricultural innovation. They represent the growing acknowledgment that innovation processes are *complex* – and in fact are becoming increasingly so – and therefore demand for the cooperation of multiple actors. In this perspective, *enabling coordinated action in a broad network of actors with various backgrounds* becomes a crucial function in innovation processes. It is precisely this function of 'enabling', which the above notions – with somewhat varying connotations – aim to capture.

Core actors engaged in the Common Agricultural Policy have picked up the terminology of 'innovation support services' and 'innovation brokerage' as well (cf. EC 2014). Some of them such as the *Directorate-General for Agriculture and Rural Development* (DG Agri), the EIP-Agri Service Point (2014, 2019), and the *Strategic Working Group of the Standing Committee of Agricultural Research on Agricultural Knowledge and Innovation Systems* (SWG SCAR AKIS) propose that, ideally, *farm advisory services* (FAS)[21] should take over these functions. They suggest that "**farm advisory services** can act as good <u>innovation brokers or innovation support services</u> because they have broad networks and [are] well-positioned to bring the right people together" (EIP-Agri SP 2019, emphases in the original). In order to be able to perform this role, it is suggested that FAS should receive greater public financial and institutional support and be more involved in the

[21] Note that while these actors generally translate FAS as 'farm advisory services', they are actually referring to the national *farm advisory systems* according to EU REGULATION No 1306/2013 of 17 December 2013 on the financing, management and monitoring of the common agricultural policy. Title III, Art. 12 of the Regulation states that "Member States shall establish a system for advising beneficiaries on land management and farm management ('farm advisory system'); and that farm advisory system shall be operated by designated public bodies and/or selected private bodies". Farm advisory systems are supposed to offer advice to farmers on, among else, the legal obligations that result from EU agricultural regulation, e.g. with regard to environmental standards, as well as on "measures at farm level provided for in rural development programmes for farm modernisation, competitiveness building, sectoral integration, innovation and market orientation […]". Importantly, as the article explicitly states, the organisations that participate in the national farm advisory system may be either public or private bodies. However, they are subject to EU- and national, i.e. public regulation. When the DG Agri et al. – as we will shortly see – juxtapose the farm advisory services they wish to strengthen to 'private' or 'commercial' farm advice, this is thus due to the fact by farm advisory services they really mean the national farm advisory systems of the EU member states. However, this distinction will be less relevant in this paper, since we will review the role of farm advisory organisations in supporting agricultural innovation more generally, not just of specific types (public/private) of advisory organisations.

development of agricultural policies and programmes than in the past (SWG SCAR AKIS 2017: 1; DG Agri 2019: 5).

This paper aims to better assess which types of organisations are currently acting as 'innovation support services', and if FAS are indeed as central to the performance of this role as the above claim suggests. For that purpose, we will first offer a short review of the general evolution of the concepts of 'innovation support services', 'innovation brokerage' etc. and make their relation to each other more transparent (2). Then, following an overview of the applied methods for data collection (3), we present some research findings from the H2020 project LIAISON[22] on 200 interactive innovation projects and initiatives[23] from the agri-food and forestry sectors that may shed some light onto the actual functional set-up of innovation processes (4). We argue that these findings indicate that, rather than farm advisors only, in practice various types of organisations provide innovation support services in agriculture. This confirms other research on that issue (cf. Faure et al. 2019; Ndah et al. 2018; Klerkx and Gildermacher 2012; Klerkx et al. 2012). We conclude that policies aimed at supporting participatory innovation processes should focus on the *functions* provided by organisations in these processes instead of devoting special attention to a particular *type* of organisation (5).

2. Conceptual background: innovation support services, innovation brokerage, innovation facilitation

2.1 Conceptual clarification

The use of the concepts of 'innovation support services', 'innovation brokerage' and the like is not unified in the field of agriculture: both researchers and practitioners use the terms differently (cf. Ndah et al. 2018). Some authors operate with quite clear-cut conceptual distinctions. The EIP-Agri Service Point, for instance, distinguishes between 'innovation support services' as a more general term, which "covers various tasks that support innovation". They see 'innovation brokerage' and 'innovation facilitation' as two distinct of these supporting tasks. In their definition, 'innovation brokerage' takes place in the *initial stages* of the cooperation for innovation and entails the following activities: 1. the discovery of innovative ideas; 2. "connecting potential partners with complementary knowledge, competences and infrastructure" ('match-making', EIP-Agri SP 2014: 3) and "taking the initiative to help them to refine the innovative idea" (EIP-Agri SP 2014: 3); 3. identifying funding sources and providing partners with a solid understanding of what criteria need to be fulfilled in order to make an application for financing (EIP-Agri SP 2014: 4); and 4. the preparation of a project proposal, which all actors involved can endorse. In contrast, 'innovation facilitation' refers to mediating activities that "bridge the language of science/markets and entrepreneurial practice" (EIP-Agri SP 2019). Unlike 'innovation brokerage', this kind of mediation needs to be performed not only at the initial stages, but continuously during the project cooperation. According to the EIP-Agri Service Point, the

[22] The H2020 project LIAISON (http://liaison2020.eu/) was launched in 2018 with the intention to contribute to the optimization of interactive innovation project approaches and the delivery of EU policies to speed up innovation in agriculture, forestry and rural areas. One key concern of the project is the identification of success conditions and challenges to collaboration in interactive innovative projects, i.e., projects in which various types of actors such as farmers, researchers, advisors and consumer organisations are actively involved.

[23] A project is carefully planned to achieve a particular aim and is characterized by a defined start and end. In contrast, networks and initiatives can be ongoing and can come from or lead to projects (cf. O'Neill et al. 2012).

supporting tasks of 'innovation brokerage' and 'innovation facilitation' may (but need not) be performed by the same person.

Similar to the EIP-Agri Service Point, Faure et al. (2019) use 'innovation support services' as an umbrella term for all activities that support cooperation and co-creation for innovation. Drawing on other studies on 'innovation support services' in agriculture, they offer a distinction of several sub-tasks of such services. Among these tasks are "awareness and exchange of knowledge" or "networks, facilitation and brokerage", the latter referring to the "provision of services to help organise or strengthen networks […]" (Faure et al. 2019: 151). So, while the authors do not distinguish as clearly between the tasks of 'innovation brokerage' and 'innovation facilitation' as the EIP-Agri Service Point, it is obvious that they as well consider them sub-categories of the broader concept of 'innovation support services'.

In contrast, Klerkx et al. (2012) and Klerkx and Gildemacher (2012) use the term 'innovation brokerage' in a broad sense that is analogous to the EIP-Agri Service Point's understanding of 'innovation support services'. In their definition, innovation brokerage is not the name of a sub-task of innovation support that should be performed in the project development phase only, but instead "be applied in a flexible and iterative manner" (Klerkx and Gildemacher 2012: 222) throughout the project. The authors propose that it is dividable into three distinct tasks, namely 1. context analysis and demand articulation (assessment of problems and opportunities), 2. network composition ("facilitat[ing] linkages among relevant actors"), and 3. facilitating interaction (cf. Klerkx and Gildemacher 2012: 222f.). In this understanding, then, innovation brokerage and innovation facilitation become indistinguishable, with 'innovation brokerage' serving as a general concept that captures, besides 'narrow' brokerage tasks, also facilitating or mediating activities.

Still other actors are using all three of these concepts interchangeably or at least without any obvious differentiation. For example, in a recent policy document the DG Agri proposes that advisors should "collect farmers' needs" and "feed these needs and opportunities into the AKIS [Agricultural Knowledge and Innovation System] for further development – **possibly as an 'innovation support service'**" (DG Agri 2019: 6, emphasis in the original). In the pursuing sentence, they say "[f]arm advisors within the AKIS should also be trained to act as **innovation brokers/facilitators**" (ibid. emphasis in the original). How exactly 'innovation support services', 'innovation brokerage' and 'innovation facilitation' relate to each other, and if they in fact designate different roles at all, remains somewhat vague.

As these few examples already demonstrate, the concepts of 'innovation support services', 'innovation brokerage', and 'innovation facilitation' are not used consistently in the agricultural field. For the remainder of this paper, however, we will adopt the EIP-Agri's conceptual distinction. That is, we will use 'innovation support services' (hereafter ISS) as the overarching notion, and to 'innovation brokerage' and 'innovation facilitation' as two distinct sub-tasks of innovation support that are performed at the beginning of or during the project, respectively. This terminology promises to avoid conceptual confusion. In addition, it seems to be particularly influential, as it informs European agricultural policy.

2.2 Background: paradigm shift in thinking about innovation

Although the respective meanings of the concepts of ISS, innovation brokerage and innovation facilitation may be somewhat ambiguous and difficult to discern, their overall emergence mirrors a paradigm shift in thinking about agricultural innovation. It testifies to the gradual transition of an understanding that considers research the main driving factor of innovation towards a 'systemic' understanding that recognizes that innovation requires the coordination of a much wider network of actors and activities. It is only against the background of this *broadened notion of innovation* that the concept of 'innovation-supporting activities' that help this coordination becomes relevant (cf. Koutsouris 2014; Ndah et al. 2018: 2; Klerkx and Gildemacher 2012: 221).

For many decades, agricultural policies in the EU have been informed by a 'linear approach' to agricultural innovation "in which new knowledge is developed through research, distributed through advisory and education services and then practically implemented by entrepreneurs" (Détang-Dessendre et al. 2018: 11). However, this approach has been increasingly criticised for not being fit to cope with the complex social reality of most innovation processes. In particular, it did not respond enough to differences between agricultural production contexts and complex natural resource management conflicts (cf. Klerkx et al. 2012: 54; Faure et al. 2019: 149).

These shortcomings led to a *first change* in the concept and practice of agricultural extension: participatory approaches to agricultural innovation emerged, whose main objective it was "to enhance research uptake and impact […] by adapting research to specific contexts and creating ownership of the research" (Klerkx et al. 2012: 54). This more inclusive perspective considered, next to the bilateral relation between farmers and research, "the broader knowledge systems in which farmers were embedded" (ibid.), or what was then labelled the 'Agricultural Knowledge and Information Systems' (AKIS).[24]

However, this adjusted approach to agricultural innovation still retained a narrow focus on research and did not recognize the importance of other, not research-related activities. Agricultural extension was largely identified with '*knowledge* brokering', i.e. the facilitation of knowledge exchange between research and practice (Klerkx et al. 2012: 54). It thus remained in a linear "transfer of technology and information framework" (Faure et al. 2019: 148), even while it had been "fine-tuned by scholars to take into account the diversity of technologies or the diversity of farmers" (ibid).

The introduction of the roles of the 'innovation broker' and the 'innovation facilitator' finally represent a shift to an *even more holistic understanding of innovation* which acknowledges that "research does not equal innovation" (Klerkx et al. 2012: 55). In this perspective, innovation consists not just in the development of new technologies but requires the active management of the interplay between these technical solutions and established social practices. In such a changed understanding, next to *knowledge* gaps between actors, "several other divides among groups involved in innovation and development" (Klerkx et al. 2012: 57) such as differences in interests/values and incentives that hinder effective collaboration have to be bridged as well. Against this background, innovation support is not something that some providers deliver to 'passive' beneficiaries in the form of linear advice (Faure et al. 2019: 148ff.). Instead, it is performed through a mutual and interactive learning process, where borders between 'providers' and 'beneficiaries' of support blur and the exchange of knowledge replaces linear instruction.

2.3 Farm advisors as innovation brokers/facilitators?

One key issue that emerges repeatedly in discussions related to innovation support services is the question of *who* is actually performing these services or who *should* perform them, and why. Many studies show that, with the increasing (acknowledgment of the) complexity of agricultural innovation processes, the division of labour between innovation partners becomes more complex as well. While traditional agricultural extension was typically performed by farm advisors who instructed farmers on "how to act to improve their firms" (Faure et al. 2019: 148), today's more complex ISS vary greatly from context to context, with a variety of actors taking over different

[24] More recently re-labelled *Agricultural Knowledge and Innovation System*, cf. Faure et al. 2019:147.

tasks in support of innovation (cf. Faure et al. 2019: 150; Ndah et al. 2018: 4f.). In one case, for instance, a private business might act as innovation broker together with a NGO as innovation facilitator, while in another agricultural industry or administrative context; these roles might be split among several organisations. Alternatively, an advisory organisation might provide both services, 'innovation brokerage' and facilitation at the same time due to the regional infrastructure.

By contrast, as mentioned above, some central actors involved in EU agricultural policy making are currently calling specifically on farm advisory organisations to take on the roles of innovation brokers and facilitators. Organisations such as DG Agri and the EIP-Agri Service Point in particular as well as some think tanks like the *Strategic Working Group of the Standing Committee of Agricultural Research on Agricultural Knowledge and Innovation Systems* (SWG SCAR AKIS) suggest that farm advisors are especially suited to perform task that support interactive innovation. For instance, on a website entry on "Innovation support services (including advisers with a focus on innovation)", the EIP-Agri Service Point (2019) argue that "[m]any advisers are ideally positioned to set up and join groups that deal with technical, financial, social, environmental or market-related issues and problems. They established a trust-based relationship, which enables them to act as brokers and which brings together farmers and others actors who can help each other". In a similar vein, the DG Agri (2019) highlights that "advisors play a key role to collect farmers' needs and opportunities, thanks to their one-to-one interactions with farmers while giving advice. They should feed these needs and opportunities back into the AKIS for further development – **possibly as an 'innovation support service'** – helping the knowledge systems to improve their impact" (DG Agri 2019: 6, emphasis in the original).

Since the activities of 'innovation brokerage' and 'innovation facilitation' go beyond the 'linear advice' that FAS traditionally performed, it is argued that FAS will need more public financial support or "a mix of public and private funding" (SWG SCAR AKIS 2017:7) as well better institutional backup than they currently have. In addition, they should be more involved in agricultural policy making, since "[s]upporting an interactive role of advisors already in the early stage of definition of policies and programmes would help creating an enabling environment to better connect practice and science" (SWG SCAR AKIS 2017:3). Without this improvement of FAS, they fear that corporate advisors, who are independent from FAS, will take over the provision of 'innovation support services' instead.[25] This will not only disadvantage small farming businesses that often cannot afford to pay for private advice, but also threaten the ideal of impartial farm advice since private advisory organisations have profit interests to consider (SWG SCAR AKIS 2017: 1; DG Agri 2019: 5).

This line of reasoning suggests that it is in a way 'natural' that advisory organisations should provide ISS. The required policy decision, in this view, is that between increasing public support for existing FAS, and surrendering innovation support to FAS-independent private advisors. In the remainder of this paper, we will re-evaluate this argument. While it raises some important concerns, we venture that it rests on a somewhat *narrow* understanding of agricultural innovation since it seems to assume that advisory organisations are the main providers of innovation support. In the following sections, we will present and discuss some preliminary findings from research in the H2020 research project *LIAISON* that suggest that other organisations such as research institutes, NGOs, producer organisations as well as agricultural education providers can take over innovation support services as well.

[25] On the distinction between FAS and non-FAS-related private farm advice, see footnote 1 above.

3. Methodology

3.1 Light Touch Review of 200 innovative projects in agriculture and forestry

In the framework of LIAISON, 200 innovative projects and initiatives in the agri-food and forestry sectors throughout Europe were subjected to a 'light touch review' (LTR). This consisted of a desk study of published material of each project (e.g. website, public documents) as well as a 'one telephone call' semi-structured interview with a key informant (e.g. the coordinator). The purpose of this review was to identify the main traits of these projects and initiatives and to determine best practices as well as challenges to collaboration both within the project and between the project consortium, external stakeholders and funding bodies. Projects and initiatives were partially identified through databases of the funding programmes Horizon 2020, INTERREG Europe and LIFE and national databases, and partially through a Europe-wide Rural Innovation Contest (EURIC) launched by the LIAISON consortium in 2019.[26]

The selection of the reviewed 200 cases from all identified projects and initiatives was based on three criteria:

- The 'insightfulness' of the project (i.e. its relevance and/or information-richness with relation to the issue of interactive innovation);
- The availability of a suitable contact person who can provide insight into collaborative processes within the project
- Funding source of the project or initiative: in each country, a set of projects and initiatives with diverse funding schemes were reviewed.

3.2 *Data from the LTR relevant to the research on ISS in agriculture and forestry*

Although the LTR was not conducted with the explicit aim of identifying innovation support service providers, the gathered data still offer insights on current features of ISS in agriculture and forestry. The following information from the LTR are particularly relevant in this regard:

- First, an overview of the *types of organisations that are coordinating the studied projects*. As we have seen before, most usages of the terms 'innovation brokerage' or 'innovation facilitation' consider 'coordination' of multi-actor processes a central part of these roles. In order to assess the importance of FAS as providers of such innovation support services, it may therefore be helpful to look at *who is actually taking over the role of the coordinator in interactive innovative projects in agriculture*. In section 4.1, we will present the pertaining LTR findings from all reviewed 200 projects and initiatives, gained through desktop surveys and verified in semi-structured interviews with project participants.[27]
- Second, information about the actual *reasons for the choice of the coordinating organisation*, which was obtained through telephone interviews ("What were the

[26] 750 interactive projects and initiatives were identified through research of EU and national databases, and 229 additional companies, projects and initiatives from 21 EU member states and two EU neighbouring states entered applications to the EURIC.

[27] We are well aware that the kind of funding a project receives will likely affect its features– such as for instance the choice of the coordinator or the role of advisory organisations within the project. For that reason, we attempted to cover a wide range of different types of EU-funded, co-funded and non-funded projects and included the type of funding as one variable in our assessment template. However, in this paper, we will not differentiate between different types of project-funding but only present general trends across the reviewed projects. More elaborated hypotheses on the causal links between the type of funding and the functional set-up of projects remains a topic for further research.

reasons underpinning the selection of the project coordinator?"). Based on the arguments given by the interviewees, we clustered their answers into different categories while allowing for multiple answers. Their responses illuminate which features in an organisation project members consider necessary for the performance of coordination and thus, of innovation brokerage and facilitation. In this way, they may also *help to understand the current extent to which FAS are performing these roles* in interactive innovation projects in agriculture. Since this paper focuses on the status of farm advisors in interactive innovation in the EU in particular, in section 4.2 we will present the findings from projects funded or co-funded by the EU[28] only, which is the case for 108 out of the 200 reviewed projects.

- Thirdly, information on the performance of two other tasks that are associated with *'innovation brokerage'* in the more narrow sense, namely the initial 'match-making' between actors and the proposal-writing. This information was obtained through two further interview questions of the LTR: "How was the project set up?" and "Who took charge of the proposal writing process and why?". In case of the first question, answers were again clustered and multiple answers allowed. We present the responses of the interviewees from the 108 reviewed EU (co-)funded projects to these two questions in section 4.3.

4. Preliminary findings

4.1 Desk survey results: coordination of innovative projects (n = 200)

If advisory organisations were indeed in a privileged position to perform the roles of innovation broker and facilitator in innovation projects in agriculture, one would expect them to be listed as project coordinators more often than other types of organisation. However, quantitative findings from the desk surveys conducted in the course of the LIAISON LTR do not confirm this expectation. Different types of organisations such as research and education institutions, businesses, individual farmers, representative/supporting institutions, public bodies, NGOs and processing/ marketing organisations led the projects. Of the studied projects, the largest share were coordinated by research organisations (30,5%), followed by farmers' representing/supporting organisations (12%), NGOs (12%), public bodies (11%), and businesses (7%). Only 4% of the project coordinators were classified as advisory organisations. The large number of projects coordinated by research institutions might be less surprising in projects that focus on policy programmes such as the H2020 RIA scheme (n= 34). In other cases such as the Thematic Networks funded under the H2020 CSA scheme (n= 16), however, we would have expected more advisory organisations to be listed as coordinators. Yet we find that none of the studied Thematic Network projects was coordinated by an advisory organisation.

Importantly, if there are only few advisory organisations among the coordinators of the studied projects, this is not because their participation in these projects would have been generally low. In fact, while research organisations were the type of organisation that was most frequently listed as project participants (155 times), advisory organisations participated at least in 104 projects – about as often as representative/supporting organisations (111 times) and processing/marketing businesses (106) and significantly more often than public bodies (91) or NGOs (76).

[28] These are (i) projects funded in the H2020 Research and Innovation scheme (RIA), (ii) Thematic Networks (TN), which are Coordination and Support Actions (CSA), (iii) Operational Groups (OG) funded under the Rural Development Programmes of the Member States, and (iv) Interreg projects.

4.2 Telephone interview results: reasons for choosing the coordinator (n=108)

Most of the interviewees from the reviewed 108 EU (co-)funded projects stated that the choice of the coordinator was in a way a 'natural' consequence of the coordinator's *pre-existing relation to the project*. That was the case e.g. where the coordinator had also developed the project idea or had been coordinating a precedent project (46 out of 108 interviews). Other important reasons for the choice of coordinator were the respective organisation's *expertise in proposal writing and/or project coordination* (36 out of 108) and its *availability of resources* (time, money, staff) (34 out of 108). Only a minority of the interviewees said that an external entity had been involved as a coordinator (9 out of 108), or that a formal 'Innovation Support Service' or 'Innovation Broker' were in charge of the coordination (6 out of 108).

These results help to illuminate why advisors are underrepresented among project coordinators, compared to their actual participation quote. They indicate that, rather than the specific *type* of organisation, what matters in the decision about whom to appoint as project coordinator is in fact a collective assessment of an organisation's *fitness* for that role. Apparently, the organisation to which a project consortium ascribes this fitness the most varies from project to project.

4.3 Telephone interview results: 'match-making' and proposal-writing (n=108)

In some of the reviewed EU (co-)funded projects, one of the consortium members took the leading role in initiating the project and invited other project partners (26 out of 108). 34 of the other projects evolved from previously existing formal and informal relationships between participants and thus in a way emerged, as one interviewee framed it, as the "logical next step". In these latter cases, no project partner took a particular leadership role in the setting-up of the project. In 22 cases, some members of the consortium knew each other from existing cooperation while others were invited to complete the group. Eight interviewees stated that a governmental organisation set up the project.[29]

These answers indicate that no specific type of organisation acted as innovation broker or initial 'match-maker'. Rather, projects either typically emerged either from previous links between the participants, or from one partner's (independent of the specific type of organisation he represents) active rallying of participants, or from a combination of both.

The findings on the organisation of the proposal writing in these reviewed projects are in line with that. The majority of the interviewees reported that the project initiator took charge of the proposal writing (57 out of 108). 24 interviewees named the expertise or formal capacity of the proposal writer as decisive factors, while 37 interviewees indicated that the members of their project's core group had shared responsibility for the proposal writing. Only nine interviewees stated that the group hired an external expert, and only three said that an official innovation support service wrote the proposal.

Here too, then, other factors than the actual type of organisation seem to affect the collective choice of who is taking charge of the proposal writing. Attribution of this role seems to depend on previous developments within the project consortium, such as established patterns of interaction between the partners and/or whether some partner was particularly involved in the initiation of the project idea. Finally, actors' expertise in proposal writing and experience and recognition in the field are decisive in the distribution of tasks.

[29] in eight cases, the answers were not clearly attributable to any of these response categories.

5 Discussion of findings

Overall, these data allow for some tentative conclusions as to the status of innovation support services in agriculture and forestry and the role which different types of organisations play in the provision of these services. One conclusion is that ISS provision is not a prerogative of specific organisations. This is because just as innovation processes become more multifaceted, so do the tasks that are required in order to initiate and facilitate innovation. Many more kinds of social divisions need to be overcome between a much wider range of actors, beyond "bridging the divide between research and practice". This may include conflicts or other discrepancies among farmers themselves, or between farmers and businesses or NGOs. In order to enable coordinated action between these actors, the social and institutional setting in which they operate will need to be changed before innovation can become effective. These brokerage and facilitation tasks, however, can be performed by *various kinds of actors*, since their successful execution depends less on specific organisational features than on experience in mediation activities and trust-based relationships within the relevant field. This interpretation confirms results from other research (cf. Klerkx et al. 2012; Faure et al. 2019).

If that is the case, however, how do we make sense of the DG Agri's, the SWG SCAR AKIS' and others' proposal that farm advisors are particularly well suited to act as innovation brokers/facilitators? One possible analysis is that while these actors refer to the *labels* of '**innovation** brokerage' and the like, the actual *framework* they apply is in fact still very much that of **knowledge** brokerage, i.e., a "transfer of technology and information framework" (Faure et al. 2019: 148). A closer reading of the above-mentioned policy papers indicates that in these actors' understanding of innovation, the transfer of research results into agricultural practice is still conceived as the core of innovation. While 'linear advice' may not be the most appropriate medium for innovation anymore, the *facilitation of coordination between science and practice*, or research and farming still appears to be the central focus of innovation-supporting interventions. From the premises of such an understanding of innovation, however, it is indeed reasonable to ascribe FAS a crucial supporting role, since the role of the intermediary between research and farming practice is the very role they have traditionally performed and that they have specialized in.

However, while such an approach may work out in some cases (cf. Faure et al. 2017), it will likely prove to be too reductive in more complex cases of innovation. If innovation support focuses too much on the optimisation of *knowledge* transfers between researchers and practice, or even among practitioners, we risk losing track of the various other linking activities that are required today to enable innovation in agriculture. Therefore, if policy-makers are thinking of ways to strengthen ISS in agriculture, rather than channelling support to specific *types of organisation*, they ought to make sure that the *functions that enable and facilitate innovation* are performed.

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HOW LASALLIAN PEDAGODY ENABLES COLLABORATIVES LEARNING: THE EXAMPLE OF UNITECH DAYS

Anne Combaud [a], Alexandre Smessaert [c], Honorine Esnault [c], Rachel Laurent [c], Alexis Belloy [b], Simon RITZ [b], Davide Rizzo [a,b]

[a] Institut Polytechnique UniLaSalle, InTerACT Research Unit UP 2018.C102
[b] Chair in Agricultural Machinery and New Technologies
[c] Institut Polytechnique UniLaSalle, Festival de la Terre et de l'Elevage – France

Abstract

Lasallian Pedagogy (LP) sprouted from the initiative of Jean-Baptiste de La Salle. Dated back to the Eighteen century, he founded a community of teachers consecrated to the education of children of artisans and the poor. With time, this became a worldwide network ran by the Brothers of the Christian schools and ministering from kindergarten to university level. Crucial for LP is the inclusive education whose key goals are: i) to professionalize students according to relevant contextual business activities, and ii) to join commitment and skills both of teachers and students in a unique community for the good running of each school. A teacher is therefore considered a mentor supporting the student's own training process rather than a "knowledge bearer". Thus, LP is natively meant as collaborative learning, with strong interactions between the students, their associations and the whole teaching community (teachers and other employees). In this paper, we analyze how LP might enable collaborative learning within the agricultural knowledge and innovation system. We focus on a farming demo recurrent event organized by a students' association belonging to the oldest high education institute of the Lasallian network. The event is named "Unitech Days" and take place yearly at UniLaSalle (campus of Beauvais, northern France). Its goal is to promote exchanges of knowledge between farmers, students, teachers, and professionals in the farming sector through demonstration of innovations. We identify two levels of collaborative learning. First, the Lasallian one, via the involvement of the teaching community in the co-organization of the Unitech Days by the student association (Festival de la Terre et de l'Elevage) that promotes it. This level implies multiple interactions that stimulate mutual learning and listening and create a peer relation between two stakeholders, students and teaching community. Second, the on-farm demonstration, aimed at enhancing peer learning in a real agricultural learning situation. These demonstrations showcase farmers' and students' technological innovations, as well as agronomic innovative projects carried by teachers, in which students are involved during their education. Altogether, students' commitment to the organization of on-farm demonstrations can enrich the collaborative learning because: (a) the students' language reaches more easily farmers, namely if one considers that they are for at least at 1/3 children of farmers; (b) students' education benefit from the beginning of a multi-actors networking including farmers and other agricultural experts and advisors.

Introduction

Farmers are entrepreneurs facing complex decisions, frequently solved through a pragmatical approach. When realizing daily farming operations, they mix traditional knowledge about the agronomical and pedoclimatic context with continuous marginal innovations. Indeed, farmers develop and carry a place-based knowledge of farming management based on an evolutive multicriteria decision-making system. For that, farmers tend to privilege learning from their peers, reckoned as the most relevant actors bringing a reliable knowledge. Yet, the deep structural changes in the European farms' structure, primarily related to the growing farm size due to the decrease in the number of famers, steadily reduce the number of accessible peers. In this regard, three projects funded by the European Commission federated to create a hub (FarmDemo.eu) aimed at describing, understanding and promoting the peer learning in agriculture, particularly through on-farm demonstrations. But how this approach could be adopted in the educational programs in agriculture?

This paper aims to present a specific approach to pedagogy adopted by a French higher education institute. After an overview of the pedagogy background and key principles, we focus on on-farm demonstration as a relevant example of collaborative and peer-learning that could enable sustainable agriculture. On these bases, we make a reflexive analysis of UniTech Days, a case study bridging the specific Lasallian Pedagogy and the on-farm demonstrations. We conclude with a few lessons learned from the students' engagement to improve farmers involvement in educational programs towards a wider collaborative learning.

1. Lasallian pedagogy

UniLaSalle is a higher education institute in Earth, life and environmental sciences in northern France, with three campuses: Beauvais, Rouen & Rennes. UniLaSalle is member of one of the largest education networks in the world: the International Association of Lasallian Universities (IALU), sponsored by the Brothers of the Christian Schools. The Brothers' congregation (identified by the Latin abbreviation FSC) dates back to the Eighteen century. In a period of elitist teaching, where pupils were usually individually supervised by tutors, they founded a community of teachers consecrated to the collective education of children of artisans and the poor; of notice, classes were composed of children coming from a same region, so teaching was contextualized to the peculiarities of this region. Their aim was to promote a broader and collective scope of knowledge. Lasallian institutions share a common identity of design and implementation of educational processes, organizational arrangements and social integration. Fundamental values are: fraternity, dialogue, participation of all educational community actors, reception of others, struggle for justice, mutual respect and solidarity (Gils and Munoz, 2013). Membership of this network implies the continuous improvement of the teaching approach based on the input and experience of other Lasallian institutions worldwide.

Lasallian colleges and universities are located in five delimited IALU regions: Asia and Pacific Islands; Central and South America; Europe and French-Speaking Africa; Mexico; and North America, Bethlehem and English-Speaking Africa (Ramirez Barba, 2018). At one time, Lasallian institutions of higher education were considered exceptional to the mainstream activities of the Brothers, who were, initially and for the most part, involved in primary and secondary education. Nowadays, each Lasallian higher educational community is challenged to address the impact of globalization, massification, unequal access, student mobility, and information and communication technology. Yet, there is no universally applicable Lasallian solution (Schieler, 2018). The current bases of Lasallian pedagogy are similar of those from the origin: they have to be contextualized, clearly related to the socio-educational requirements of each country (i.e., *delimitated state*) of the IALU network, without losing the bases that define and express its identity (Rangel, 2011). Universities implements a transformative, learner-centered approach to education. For example, UniLaSalle holistic approach is based around three components:

taking care of the needs of each and every young person entrusted to us;

recognizing that everyone has a role to play in our educational approach;

developing a sense of fulfillment based on commitment and individual responsibility.

Those components are inspired by the didactic principles of FSC Congregation founder, Jean-Baptiste de La Salle, adapted to contemporary pedagogy. In this article, as in Lasallian institutions, *pedagogy* is intended as the educational context, whereas *education* is understood as the daily school practices, in the broadest possible sense (Munoz, 2011); finally, *didactic* is meant as the study of the educational act of teaching (Rangel, 2015).

Based on Rangel (2015) we can summarize the actualization of original Lasallian didactic in contemporary didactics through eleven principles, with a focus on the complementary between theory and practice in teaching-learning.

Affection - The education inclusive is based on the principle of foster care and respect for individual characteristics and their differences without discrimination. Therefore, students learning capability and sensitivity are emphasized in Lasallian didactic.

Dialog and example - The dialogue involves for teachers a role of accompaniment to mentor the students and not a limiting role of trainer. Lasallian schools create a personalized relationship between teachers and students, and environments that are conducive to community life.

"The school 'runs well" - The valorization of coexistence (of "co-existence", the existence in collectivity) is one of the main formulations of La Salle, inserted in its democratic action. To strengthen community life, La Salle campuses offer a combination of living spaces and class, to perform knowledge, associative responsibility, relationship and sports. The development of these living spaces reaffirms their importance for learning, as an environment conducive to didactic relations and collaborations between teachers and students and among teachers.

Discipline and moderation - Discipline is a condition and a learning imperative: acquisition of knowledge requests attention and concentration. For La Salle, the less the teacher speaks better. This involves making the student active in his learning to promote his attention and his memorization. Therefore, La Salle institutions must deploy a set of conditions to promote learning, without dispersions or negligence.

Contextualization - When La Salle instituted collective preparation for life and work, he created the principle of contextualization. Contextualization fosters the relation practice-theory-practice. That relationship is especially indicated in the current didactic approach.

Didactic transposition - Didactic transposition consists in transposing the knowledge, transposing the theory to the level of learning of the student, according to the age and the study level. In this approach, the proximity between teachers and students is fundamental: a presence of the teacher close to student and an accessible language constitute principles of the Lasallian pedagogy and one of his significant contributions to teaching.

Multiple methodologies - choose from multiple methods the best one suited to the content, the student and the context. Teachers tailor their resources to the nature of knowledge and of students.

Learning as a means of social emancipation - Lasallian institutions practice teaching based on learning by doing, including try to get knowledge valor, its importance, its political implications, for the interests of all the community, and not only of social privileged groups. Education becomes a process (and right) of social emancipation.

Collective decisions: integration - Collective decisions apply to all pedagogical procedures: objectives, contents, methods, evaluation, as well as for material. Community decisions need collective awareness value of the learning-by-doing, that makes sense of the practices.

Organization and planning - The organization, with a planned teaching-learning is one of the criteria of didactic process, thus for forecasts and for the planning of practices, in their circumstances and factors. Organization, forecasting, planning help the teaching-learning process and brings flexibility, and lessen improvisations, analyzed for their effects on insecurity of students and teachers.

Competent mentor-teacher - Qualitive pedagogical practice for a democratic and not elitist learning requires a competent teaching. LaSallian institutions offer vocation training to mentor-teachers, for a teaching lead to learning, by prioritizing the *coexistence*.

To conclude on the Lasallian pedagogy, the identity of a Lasallian school deals with such "deep simplicities", more acquired through experience than through description. The core principles have also come to articulate an accessible set of pathways for Lasallian students to recognize, appreciate and promote their personal experiences in a Lasallian school (Van Grieken, 2019).

2. Collaborative learning: focus on on-farm demonstration

Approaches to knowledge exchange, learning and innovation in agriculture are rapidly evolving. Agricultural Knowledge and Innovation Systems (AKIS) is used to describe news ways people and organizations interact. The 'linear knowledge transfer' model is becoming increasingly outdated and peer learning between farmers is becoming increasingly important as well as co-creating knowledge between all the stakeholders (EIP-AGRI, 2018).

2.1 Concept of participatory education in agriculture

In agricultural higher education, *inter-disciplinary* education is promoted to the detriment of *disciplinary* education (Gibbon, 2012). In a didactic inter-disciplinary approach, experiential learning constitutes an integral part of education (

Table 5).

Table 5: Differences between disciplinary and inter-disciplinary education (source: Gibbon, 2012).

DISCIPLINE BASED	INTER-DISCIPLINARY BASED
DEVELOPMENT OF BEST TECHNICAL MEANS	Adaptive performance based on adaptive learning
EXPERT BASED RESEARCH	Collaborative research, including farmers
CROP DISEASES AND CROP PROTECTION	Integrated pest management
NUTRIENT DEFICIENCIES	Integrated nutrient management
TEACHING	Adult education approaches and experimental learning
POSITIVIST-REALIST EPISTEMOLOGY	Constructivist epistemology
PROBLEM SOLVING	Situation-improving
LOGIC OF CAUSATION	Logic of reasons

In an inter-disciplinary research approach, scientists must work together as a team to share understanding and interpretation of how they see the system working and the dynamic interrelation between elements and structure (Gibbon, 2012). Tress and colleagues (2005) further specify that the inter-disciplinary approach involves several unrelated academic disciplines in a way that forces them to cross subject boundaries to create new knowledge and theory and solve a common research goal. Moreover, *trans-disciplinary* both integrates academic researchers, from several unrelated disciplines, and non-academic participants, involving cooperation among multiple stakeholders of society (Gibbon, 2012; Tress et al., 2005). Trans-disciplinary combines interdisciplinary with a participatory approach. Participartory studies are not research exclusive and can include academic goals (Figure 5).

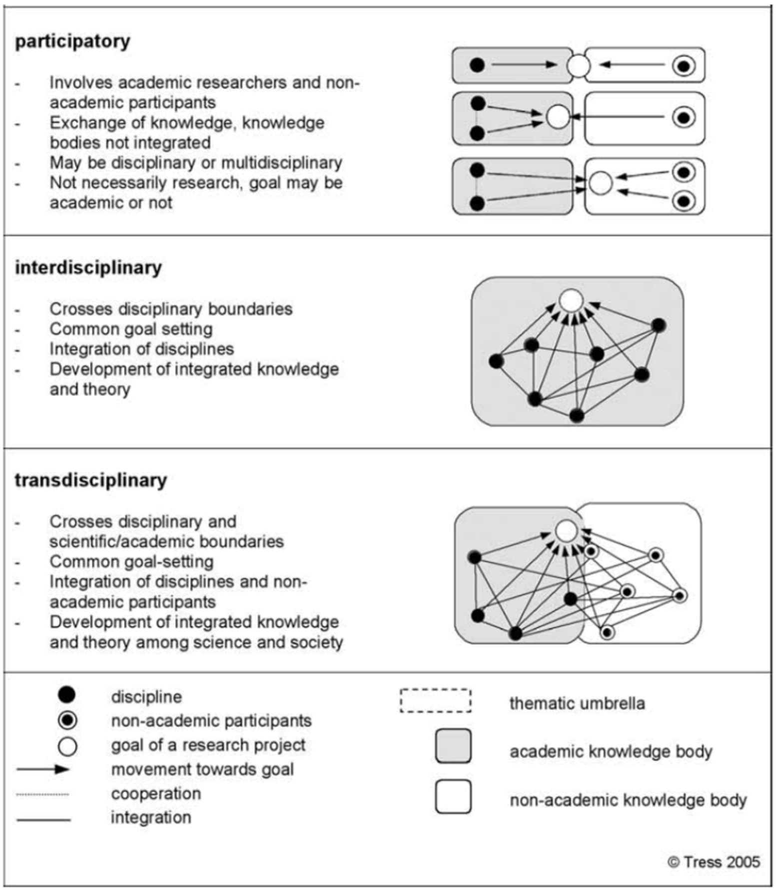

Figure 5: Overview of concepts (Tress et al., 2005)

In participatory methodologies four principles unite all agricultural contexts (Gibbon, 2012):

A systematic and group-learning process

The acceptance of the multiple perspectives of stakeholders

Facilitation leading to transformation

Learning leading to sustained action.

Those principles are quite equivalent of some Lasallian didactic principles: group and rather than individually focused; principle of dialog and collective decisions; principle of contextualization; principle of multiple methodologies.

2.2. Collaborative learning: a didactic participatory methodology

In educational research, collaborative learning (CL) refers to instructional arrangements that involve two or more students working together on a shared learning goal. CL emphasizes the importance of positive interaction among students: during CL, students are encouraged to ask questions, give elaborate explanations, exchange arguments, formulate new ideas and problem solutions, and so on. However, these positive results can only be achieved when teachers make adequate instructional decisions. Particularly while students are collaborating, teachers are expected to monitor which problems the students may encounter so as to intervene when necessary (van Leeuwen and Janssen, 2019).

Collaborative learning involves some Lasallian didactic principles such as principle of dialog and example; principle of discipline and of moderation; principle of contextualization; principle of didactic transposition.

A declination of collaborative learning is the peer learning (also referred to as peer-to-peer learning), when learners become themselves mentors. Peer learning suggests a two-way, reciprocal learning activity. Peer learning should be mutually beneficial and involve the sharing of knowledge, ideas and experience between the participants (Bould et al., 2013) This reciprocality requires initiative, active participation and engagement of the learner towards the own learning process. Peer learning is not student exclusive and is deployed in agriculture between farmers, particulary during on-farm demonstration (Cooreman et al., 2018).

2.3. On-farm demonstration: an example of peer-learning for sustainable agriculture

On-farm demonstrations have been organized originally to introduce farmers to innovation, but more recently also to share experiences in a farmer-to-farmer setting (peer learning), and to support knowledge co-creation between farmers and other actors. As peer learning is not merely a single practice but covers a wide range of different activities (Cooreman et al., 2018), on-farm demonstrations aim at one or more of the following (Pappa et al., 2018):

research implementation: established by researchers to validate and demonstrate new technologies;

knowledge creation, development and processing on demonstration farms: results of cooperation between farmers, specialists, researchers, fields advisors;

demonstrating new technologies-innovations uptake: to make clear what is entailed in opting for a new farming innovation;

knowledge transfer, educational and training opportunities: to get advice, information and knowledge on a wide variety of topics from advisers and specialists;

policy implementation: to become aware of regulations and supply chain standards;

networking: strengthens links between producers and their markets, the food chain industry, local communities and authorities, consultants and national agencies;

locally oriented implementation, participating processes enhancement and feedback opportunities: links education provision with the needs of local farmers and ensure that researches and solutions are directly relevant and focused on farmers' needs.

3. UniTech Days: a Lasallian on-farm demonstration

To explain UniTech Days, the seven categories of an on-farm demonstration are taking back (Marchand et al., 2017). For each category, the main Lasallian didactic principle is itemized.

3.1. Context: principles of collective decision and dialog

Organized yearly, the UniTech Days represents the completion of a year of interaction between the stakeholders involved in their organization process. Co-organizers are the students, throughout a dedicated association (Festival de la Terre et de l'Elevage), UniLaSalle agricultural academic staff and Chair in Agricultural Machinery and New Technologies (Chair AMNT) members (Figure 6). The initiative comes from the students' association and the first edition took place on April 11th, 2019.

The main goal was collectively defined to promote exchanges of knowledge between farmers, students, teachers, and professionals in the farming sector through demonstration of innovations.

3.2. Goal of the demonstration: principle of contextualization

The theme of the day was "Innovation by Farmers", to highlight farmers' levers on the farm, to turn an innovative idea into action and understand the innovation process. To incite students' participation during this first edition and create peer learning between actual and future farmers, organizers decided to select some innovations demonstrated through students' projects. The day was organized around three possible innovations:

technology: innovative soil tillage equipment demonstration, some of which engineered by UniLaSalle students and alumni;

agronomy: visit of experimental plots included in a systemic territory project of agricultural biomass valorization, involving UniLaSalle researchers and academic students' projects;

organizational: two plenary conferences and *in-situ* demonstrations.

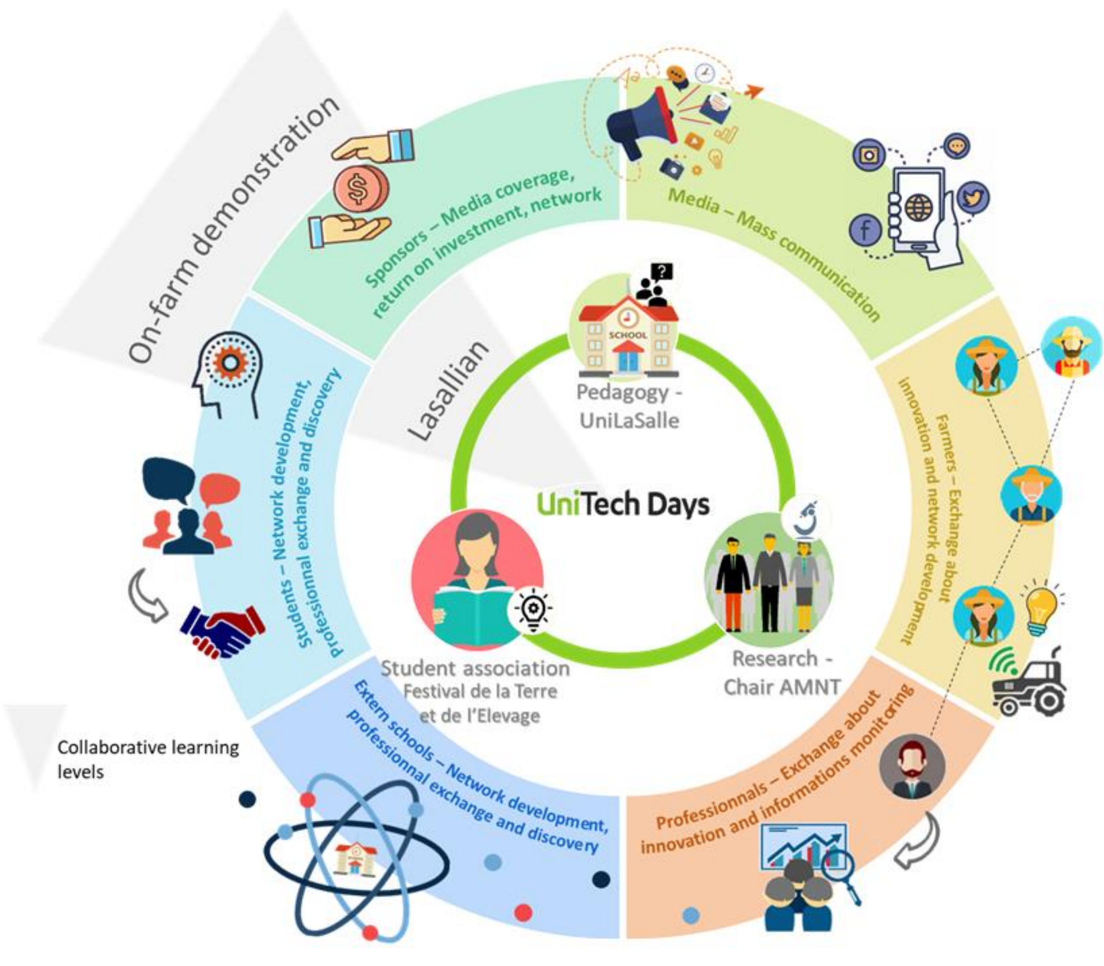

Figure 6: Unitech Days – two collaborative levels: Lasallian and on-farm demonstration

3.3. Host farm & logistics: principle of organization and planning

The locations used where tailored for the objectives of the day: farm demos have to occur on a farm to promote peer learning between actual and future farmers. The Unitech Days take place on UniLaSalle Beauvais campus, into three different spaces:

the UniLaSalle experimental farm, located on the campus;

AgriLab, a FabLab dedicated to open innovation towards sustainable agriculture, spanning from equipment to digital tools;

the academic building.

As organization was carried by a UniLaSalle student association, placed the event on campus facilitate logistics, allow to use all infrastructures (parking, university restaurant, signage ...) and strengthen relations with students during the all day.

3.4. Demonstration set-up: principle of the school 'runs well and didactic transposition

For technology and agronomy innovations demonstrations, co-existence of students', researchers', alumni', and professionals' demonstrations was favored. Groups included professionals, researchers and students, from UniLaSalle and others. We focus here only on the technology demonstration.

Technology: demonstration of 3 strip-tills, designed and prototyped by and for farmers. During demonstrations, the participants were split into three groups, and each demonstration was repeated three times for 20 minutes. The strip-till is a soil tillage tool that to prepare the seedbed only on the seed line, thus allowing to preserve the previous crops residues to cover the space between rows. It is one of the tools used in conservation agriculture, particularly targeting soil protection. The highlight was the demonstration of the strip-till designed and prototyped by UniLaSalle's students. It attracted the interest of many professionals because this type of strip-till with hydraulic driving is little known (Rizzo et al., 2018). This is a great example of a successful student farming knowledge transposition.

3.5. Recruitment: principle of learning as a means of social emancipation

Target audience is clearly actual and future farmers. Invitations have been sent to agricultural upper secondary and post-secondary non-tertiary education schools, agricultural professional organizations. Several networks were mobilized to disseminate information:

Students' network: as minimum 30% of agricultural students are sons or daughters of farmers, they mobilized their own network, especially president of the association, with high local network. Association creates a dedicated web page (https://www.festival-terre-elevage.com/unitech-days-vegetal);

Alumni' network: publicity was disseminated in newsletters and website. Alumni network has more than 18000 alumni around the world, with almost 200 farmers in Northern France;

Chair AMNT' network: a diffusion was published in the monthly newsletters, send to more than 200 alumni of UniLaSalle, prospects, professionals and farmers.

Altogether nearly 270 people came, including 170 students, from UniLaSalle, other schools or higher education, and 100 professionals, including 35 farmers.

3.6. Learning and facilitation methods: principle of multiple methodologies

Along with peer exchanges – students / farmers – several knowledge exchange methodologies were used:

Promoting interactions by putting the actors of innovation as center of attention: the innovative farmers were offered the opportunity to present their innovation with their own language and communicate about it. For the students presenting innovative works, they had the responsibility to communicate beyond the academic circle of usual staff, etc.

Presenting the technological innovations in the field despite the cold weather and soil humidity gathered participants around the farmers' usual dilemma of intervening in the field with hazardous climatic conditions. Even though tools could not be demonstrated running due to the humid soil conditions, participants expressed satisfaction to bond outside around innovative farm machinery;

Use of technological tools to promote live feedback from the audience during presentations (conference and panel but also and more importantly during introduction and conclusion of the day) i) generated a lot of interactions: students gained in confidence by interacting with a tool they know well (smartphone or computer) and farmers expressed interest for this interactive method; and ii) placed the participants in a perspective of bottom-up knowledge sharing.

Time management throughout the day has been guaranteed by changing of locations for each activity of the day: several rooms, fields, spaces were allocated for a specific time. There were no significant delays at the end of the day and participants expressed satisfaction about the load and repartition of activities (inside / outside) throughout the day.

3.7. Follow up and evaluation: principle of organization and planning

This event was considered a success as interactions were reckoned by all as beneficial for main targets, actual and future farmers. The role successfully taken by the students illustrates their ability to evolve from learner to mentor, in their turn.

Overall, collaborative learning was implicit and explicit throughout the whole process or organization & implementation (Lasallian level of collaborative learning) and during the day for the participants (on-farm demonstration level of collaborative learning).

The generated interest induced an availability of funding for the organization of the next UniTech Days 2020.

4. Conclusion

We proposed an interlocking collaborative learning to integrate on-farm demonstration in students' background and promote their ability of farming knowledge transposition. On these bases, we can draw a few lessons about the peer learning.

First, the implementation of Lasallian principles, in particular via the co-organization of the Unitech Days by student association and UniLaSalle staff. This level implies multiple interactions that stimulate mutual learning, dialog and collective decisions and create a collaborative relation between members of a unique community, dialed by students and mentors.

Second, the on-farm demonstration, aimed at enhancing peer learning in a real agricultural learning situation between actual and future farmers. These demonstrations showcase farmers' and students' technological innovations, as well as agronomic innovative projects carried by teachers, in which students are involved during their education. This event demonstrates that contextualization during an on-farm demonstration and co-existence of actual and future farmers can promotes peer learning, when learners are not considered as student or professional but future and actual farmers.

Altogether, students' commitment to the organization of on-farm demonstrations can enrich the collaborative learning because: (a) the students' language reaches more easily farmers, namely if one considers that they are for at least at 1/3 children of farmers; (b) students' education benefit from the beginning of a multi-actors networking including farmers and other agricultural experts and advisors.

To succeed further in Lasallian pedagogy, it would interesting to study how agricultural universities members of IALU promotes on-farm demonstration by students on their own experimental farms. As all of our engineers' students study abroad in a Lasallian agricultural universities for one semester, we can include this comparison in one course of the curricula dedicated to comparative analysis of agricultural systems.

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Author contribution. All the authors conceptualized the framework and the research challenges. DR and AC curated the selection and analyses of relevant documents. AC DR and SR wrote and edited the text, students schematise the Unitech Days in a synthetic figure and all of revised the article.

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DEVELOPMENT OF AGROFORESTRY 'MASTERCLASSES' TO OVERCOME POTENTIAL BARRIERS IN THE FLEMISH CONTEXT

Debruyne, Lies[a]; Triste, Laure[a]; Koopmans, Marlinde[a]; Reubens, Bert[a], Leyequien Abarca, Euridice[b]

[a] Research institute for Agriculture, Fisheries and Food (ILVO)
[b] Van Hall Larenstein University of Applied Sciences

Introduction

Agroforestry as a way to transform agriculture

Agroforestry (AF) is a system where trees or shrubs are combined with crops and/or livestock, with the aim to deliver novel products and/or services. AF has been recognized for nearly half a century as a sustainable agricultural practice (Nair & Garrity, 2012), and the concept of integrating trees into the agricultural landscape is as old as the practice of cultivating land (Wilson & Lovell, 2016). However, agricultural practices have changed quite significantly over the last decades. Agricultural production has more than tripled in the last 50-60 years, due to processes of intensification and expansion (FAO, 2017). These processes have however come at a cost to biodiversity, ecosystem functioning and climate, as well as product quality, animal welfare and human health (Martin et al., 2013). To address these challenges, approaches that protect and improve the natural resource base are needed. This could imply technological improvements such as climate-smart agriculture, but also agroecological farming systems that build on traditional knowledge, like AF. The beneficial outcomes of AF include reductions in nutrient and pesticide runoff, carbon sequestration, increased soil quality, erosion control, providing shelter for livestock, and diversification in production and increased resilience, at least on the condition that suitable trees are selected and appropriate tree management is applied (e.g. Caudill et al., 2015; Davis et al., 2012; Dixon et al., 1994; Jordan & Davis, 2015; Nerlich et al., 2012). The fact that AF systems can simultaneously provide economic, ecological, and cultural benefits to famers and the wider society gives AF great potential as a transformative solution, to deal with the aforementioned challenges (Borremans, 2019; Wilson & Lovell, 2016).

Agroforestry implementation in Flanders

Flanders is one of the few regions in Europe which supports AF systems through both pillars of the CAP. As part of the first pillar, AF systems were qualified as Ecological Focus Area. As part of the second pillar, Flanders included AF in the list of agri-environment measures and management agreements eligible for subsidies. This resulted in 2011 in the set-up of a subsidy program for the installation of AF plots, which was renewed in 2014. Through this subsidy, farmers can retrieve up to 80% of the investment made when implementing an AF system. However, the Flemish subsidy program only finances 'AF *sensu stricto*', following the rather narrow definition of AF as defined in the Flemish regulation (Borremans, 2019; Departement Landbouw en Visserij, 2019), which excludes windbreaks, shelterbelts, dispersed trees in grassland and rows of trees at the border of agricultural fields. Typical AF systems in Flanders are intercropping systems (regular tree rows with an agricultural crop planted in between the rows) and trees in grassland (in combination with livestock). In addition to the subsidy as a supportive measure, the consortium 'Agroforestry Vlaanderen', encompassing the main actors working around AF in Flanders, offers support to anyone interested in implementing an AF system.

However, despite the possible associated benefits and existing support measures, the adoption rate of AF in Flanders remains below the initial expectations (Borremans, 2019). Borremans et al. (2018) investigated the barriers for AF development in Flanders. They identified challenges related to, amongst others, lacking technical knowledge, financial constraints, legal uncertainty, lacking organizational support, and social pressure. Based on these challenges and the already existing merits of the agricultural system in Flanders, they suggested 5 development pathways focusing on i) science and technology, ii) market and financing, iii) policy and institutions, iv) education and organization, and v) social and behavioural aspects. They also propose several strategies and actions for each of the development pathways to overcome the existing barriers.

In the following sections, we will first describe the FarmLIFE project, with a focus on the organization of the masterclass programme, followed by a brief literature review on the potential of masterclasses as a learning approach. Second, we describe in more detail the set-up of the masterclass programme, and the evaluation approach. Third, we describe preliminary results of the masterclass programme in Flanders, discussing i) the value of the first masterclass series in Flanders, and ii) the potential of the masterclasses to contribute to the development pathways described by Borremans et al. (2018). We conclude with a short description of the next steps in the masterclasses programme, and suggestions on a further evaluation of the programme.

At this stage, this paper is an introductory part of a study that is still being conducted, and presents only preliminary results.

FarmLIFE as a platform to support learning on AF

The FarmLIFE project

FarmLIFE is a 5-year project funded by the LIFE+ programme, aiming to support the EU climate policy priorities. Main objectives of the project are to enable the transition of conventional agriculture towards climate resilient agroforestry. This is done through two main elements. First, the project cooperates with 3 landowners to develop adaptive farm plans for three AF sites, which in time should serve as demonstration sites for innovative adaptation measures. Second, the projects aims to develop and test replicable learning tools for connecting farmers and other societal partners in resilient rural networks. For the second objective, several actions have been formulated, including the organization of a 'masterclass' series, both in the Netherlands and in Flanders (Belgium).

In the course of the 5-year project, 2 sets of 18 masterclasses are being organized (with an intended average of one masterclass per month), both in the Netherlands and in Flanders. Main objective of the masterclasses is to facilitate the transition towards more climate-adaptive AF systems by creating a supportive learning environment for farmers. During the masterclasses farmers have the opportunity to engage with various societal partners (researchers, technical experts, government representatives, businesses, institutes, consumers), to share concerns/questions, and jointly discuss existing concerns/questions, address these issues, and define possible solution strategies. The masterclasses intend to support an educational approach based on learning rather than on teaching. The content of the masterclasses is as much as possible demand-driven, using flexible & interactive learning tools, which can include training sessions, demonstrations with hands-on activities for the participants, field visits, but also presentations on specific topics by experts, group discussions, etc. More information on FarmLIFE: http://farm-life.eu.

The masterclass programme as a learning approach

A learning approach may be understood as a patterned set of generalized ingredients and relationships that are promoted as desirable for the learner and the learning outcomes (OECD, 2013). Approaches vary in terms of e.g. student-teacher relationship, individual versus community emphasis, active and passive knowledge building and so on. The masterclasses fit well within current ideas on of knowledge sharing and (co-)creation to support more sustainable farming system. The objective of creating a setting enabling opportunities for joint problem solving is in line with the increased acknowledgement of the importance of knowledge co-creation - as opposed to unilateral knowledge transfer – processes, focusing on interactions between science and society, and where farmers are recognized as equal co-producers of knowledge (Moschitz and Home, 2014; Sumane et al., 2017). In this transdisciplinary approach for knowledge co-creation, networks and communities of practice (CoPs) are increasingly used as ‘tools’ in knowledge management (e.g. Oreszczyn et al. 2010; Wenger et al. 2011). Wenger et al. (2011) define CoPs as learning partnerships among people who find it useful to learn from and with each other about a particular domain, use each other’s experiences of practice as a learning resource and join forces to address individual and collective challenges. Also, Curry et al. (2012) report on the importance of networks in which farmers develop knowledge and innovation from the ‘bottom up’, through mechanisms of sharing experiences and learning together.

The concepts of tacit knowledge and peer-to-peer learning are central in such configurations. Tacit knowledge is considered as indispensable in processes of sustainable development, because it is context-specific and holistic (Hoffman et al., 2007; Curry & Kirwan, 2014; Sumane et al, 2017), encompassing both an individuals’ skills and crafts and mental models, ideas and values (Nonaka & Takeuchi, 1995; van den Ban, 2002). Two types of processes have been considered as pivotal in knowledge co-creation processes, because they enable tacit knowledge sharing, i.e. “socialization”, which is supported by practical experience, interactions, and observing practices, and “externalization”, where the tacit knowledge is transformed to new, explicit concepts, making them more easily shareable (Nonaka & Takeuchi, 1995; Hoffman et al, 2007).

Second, the concept of peer-to-peer learning refers to a reciprocal, at least ‘two-way’, learning approach between equals. Important and characterizing is what Cooper (2002, p.54) explains: ‘Peer learning represents a major shift in focus from what is being taught to what is being learned, and transfers great responsibility for knowledge acquisition, organization, and application from the traditional teacher role to the student”. It requires initiative, active participation and engagement of the learner towards the own learning process, and emphasizes learners learning from and with each other (mutual learning). Roles of teacher and learner are not necessarily defined and can alternate throughout the learning experience (Boud et al., 1999). Research has indicated consistently to the fact that farmers put great value to peer learning experiences (e.g. Oreszscyn et al., 2010; Hamunen et al., 2015).

As a final element of the learning approach, we would like to highlight the importance of competency development. It has been argued that education should be aimed more at developing specific competencies in farmers, focusing on e.g. rich observation, creativity, and critical reflection (Lieblein, et al 2012; Debruyne et al, 2016), rather than merely “providing” knowledge, when considering agroecological farming systems, like AF, where a holistic view on farming is crucial (Francis, 2004). Developing such competencies also requires specific educational methods, requiring a good balance between experience, theory, and the acquisition of practical skills, with learners being embedded in the context of the farming system (Lieblein et al., 2004; Hilimire et al., 2014).

These various aspects are the foundation for the format of the masterclasses: a series of meetings, in relatively small groups, ideally with at least a core groups of steady participants, expertise being provided as much as possible by peers, with sufficient space for interaction, hands-on experience, and peer-to-peer discussions, and with learners taking responsibility for what is being learned. As such, the idea is to develop a community of practice through the masterclass programme, bringing together (future) AF farmers and other societal actors in Flanders.

Methodology

Case description: developing the masterclass programme in Flanders

In Flanders, the first set of 18 masterclasses has been organized between September 2018 and March 2020. This first set consists of three main 'types' of masterclasses. First, a set of 3 exploratory masterclasses was organized, followed by two parallel sets of masterclasses: a first 'general' set of 9 masterclasses, focusing on a range of diverse, quite practical topics, and a second set of 6 so-called place-based masterclasses exploring the possibilities of AFs in a specific area in Flanders (Bulskampveld). They are discussed in more detail below.

Identifying needs through exploratory masterclasses

We started with 3 "exploratory masterclasses", each with a specific aim. The first exploratory masterclass had 12 farmer participants with a clear interest and/or stake in AF (e.g. have an AF system implemented on their farm), and with clear pre-existing knowledge on the topic.

In a previous research project, a list of interests and needs were already compiled. Our aim for the first masterclass (MC1) was i) to validate and confirm that the interests and needs were relevant, and ii) to identify possible other actor types which influence decision making around AF. This was done through a network mapping exercise for 3 participating farmers, identifying societal actors (i.e. specific organizations, institutes and actors, other than farmers) who had played a part (either positive or negative) in the development of the AF system on their farm.

This input was used to organize a second exploratory masterclass (MC2). Since the aim of the masterclasses is not only to engage farmers, but also other societal actors, the latter was the target audience. Based on input from MC1, and own expertise, societal actors deemed as relevant and/or having an impact on the AF implementation in Flanders including policy makers, from different policy levels (regional/Flemish; provincial; local), and from different policy domains (agriculture and forestry; environment, heritage), advisory services (both public and private), and companies/industry representatives (from the demand and supply side) were invited. The aim of MC2 was twofold. First, identify their views about the potential of AF in a Flemish context, and if and how AF can contribute to achieving their own (organization/institute/company) objectives. Second, identify their needs for a masterclass programme. The MC2 had 22 participants, and resulted in 5 main topics to be considered for the masterclass trajectory: 1) AF business models, 2) place-based approaches for AF, 3) choice of suitable species and cultivars, 4) existing barriers for AF implementation and 5) chain organization.

A third masterclass (MC3) was organized for a wide audience. The main aim of MC3 to broaden the potential masterclass audience also including people with little or no knowledge on AF. The MC3 was organized at AgriFlanders, the main agricultural fair in Flanders, and attracted 62 participants, with diverse profiles (policy makers, researchers, advisors, active farmers and foresters). During this masterclass an introductory presentation was given about the concept of AF, and what it could mean in a Flemish context followed by a testimony of 4 AF farmers and a discussion.

Finally, a fourth masterclass was organized with a focus on the current and future policy around AF in Flanders, with a selected group of participants, active in policy, but also including 3 AF farmers, specifically to capture their experiences, and possible shortcomings or points of improvement for the current AF policy.

Developing a general and place-based series

Based on the input of the 3 exploratory masterclasses (and previously identified needs of the AF farmers), a programme for the remainder of the first set of masterclasses was proposed.

One of the main elements emerging from the exploratory masterclasses, was the fact that a transition towards more climate-adaptive AF systems would be well served by following a place-based approach. The latter is defined as “integrated management of the full suite of human activities occurring in spatially demarcated areas identified through a procedure that takes into account biophysical, socioeconomic, and jurisdictional consideration” (Young et al., 2007). In such an approach, local actors are brought together to develop a shared vision on the potential of AF for their specific area, taking area-specific characteristics and conditions into account. The idea being that the space shapes the potential for development of territories, and the individuals who live in them (Barca et al, 2012; Reed et al, 2017).

We thus developed two parallel trajectories: i) a series of general masterclasses, open for all interested, and ii) a series of place-based masterclasses, targeting specifically local actors within a specific area. Topics for the general series cover a wide range of elements, based on both farmers’ and societal actors’ needs, identified during MC1 and 2 (Table 1).

Table 6: overview of the masterclass programme

Exploratory masterclasses	
10/18 – Validation farmers’ needs + inventory societal actors 11/18 – Identification societal actors’ needs 12/18 – Reflection on AF policy in Flanders 01/19 – AgriFlanders information session: AF for a wider audience	
Place-based series	**General series**
01/19 – exploration Bulskampveld (meeting with regional coordinator and administration)	03/19 – Winter pruning of fruit trees
04/19 – meeting with the local working group (programmateam) agriculture	04/09 – Food forests
09/19 – meeting with different management authorities	05/19 – Holding pigs in AF systems
11/19 – meeting with public/private advisors active in the area	06/19 – Designing an AF system on your farm
TBD further	07/19 – Choosing suitable planting materials
	09/19 – Summer pruning – processing and marketing of fruits and nuts
	11/19 – Creating added value for AF products

	02/19 – Short chain marketing of AF products 03/20 – Wood products from AF (high quality & biomass)

For the general series, a list of topics was proposed for the whole series, based on the input obtained during the exploratory MCs, with a best suggested time for each masterclass. Some flexibility was still possible, depending on availability of experts, and participant questions during the masterclass series. Masterclasses in general followed a similar set-up: the masterclass included one or more presentations (e.g. farmer offering a testimony about AF on their farm; expert[30] providing background to the topic of the day) and one or more interactive sessions (e.g. farm walk, field visit, Q&A session, workshop). Participants registered beforehand, and at the time of registration had the opportunity to indicate specific questions they had regarding the topic of the masterclass. These questions were shared between facilitator and speakers, and were, whenever possible, integrated in the presentation and/or discussion during the masterclass. The number of participants varied between 16-47. In total, we had 185 participations for the 6 masterclasses which had taken place at the time of writing. Of those 185, 107 were individual participants. A core group of 15 people attended 4 or more out of 6 masterclasses, and 57 participants only attended one masterclass.

For the place-based series the area 'Landschapspark Bulskampveld' (BKV) was selected. This area is situated on the border of the provinces of East- and West-Flanders, and covers a surface of approx. 100 km² (Figure 1). This area was designated in 2012 as a development area by the Province of West-Flanders, with a focus on the themes of culture, landscape, nature and recreation.

Figure 7: Location Landschapspark Bulskampveld (delineated in red) within Flanders. Source: www.agiv.be

We selected this area for several reasons: first, because of the aforementioned ongoing developments within the area, there is already a quite strong interaction between actors in the area, so we can build on a pre-existing network, which is an important consideration considering the time constraints of the project. Second, agriculture has historically played an important part

[30] experts had different profiles, and could either be farmers, researchers, advisors, etc., but all with a strong practical experience in AF.

in the area (Demasure, 2013), so there is a clear interest in developments where agriculture can contribute to the aforementioned focus themes. Third, a short visionary document regarding opportunities for AF in the region, has been developed by mainly the regional administrators, which needs to be aligned with the other actors active in the area. So, one of the main objectives of the place-based masterclasses is to develop a shared vision with all main local actors on what AF could mean for them in the area, and identify how an integrated vision on the implementation of AF in BKV can assist them in achieving their own (personal/organizational) objectives (e.g. diversification of farm income, creating corridors for bats, restoring cultural-historical landscapes, etc.). At the same time, the potential of AF implementation on approx. 5 farms within the area will be explored more in detail.

Evaluation set-up

We included 3 main elements in our evaluation: i) creation of a supportive learning environment for famers and other actors, including aspects on the learning approach that was followed (demand-driven, interactive & flexible); ii) creation of opportunities to engage with various societal partners; and iii) elements for improving the practical organization of the masterclass (less specifically linked to the objectives). We developed a stepwise evaluation approach, which differs for the place-based and general series, considering the different focus and approach of both.

For the general series, experiences of masterclass participants were captured through a short questionnaire sent to all participants within one month after each masterclass, and a short focus group towards the end of the first series of general masterclasses. The short questionnaire is structured similarly after each masterclass, and has a number of open and closed questions (Table 2). Questions are designed to mainly evaluate item 1 (learning, focusing on short-term outcomes of masterclass participation) and 3 (practical evaluation). Out of 185 possible responses, we collected 56 completed questionnaires after 6 general masterclasses (response rate 30.3%). The focus group was held in Nov. 2019, and had 18 participants, and followed a world café approach. The focus group covered all 3 aforementioned elements (learning, networking opportunities, practical organization).

Table 7: Evaluation questionnaire general masterclass series

Section 1: masterclass announcement	
How did you find out about this masterclass?	Personal invitation Website AF Vlaanderen Social media Agricultural press During a previous masterclass Other
What triggered your interest to participate?	Open question
Section 2: practical organization	
How would you evaluate the different sections of the masterclass	(Per session) very useful useful

	neutral not useful
What did you find the most interesting element in this masterclass?	Open question
What was well organized about this masterclass? Why?	Open question
What was not well organized about this masterclass? Why not, and how could it be improved?	Open question
Which aspects of the masterclass are applicable to your company or within your organization and field of work? Why?	Open question
Section 3: learning	
Do you intend to apply what you learned during the masterclass in practice?	Yes no maybe
If your answer is yes or maybe, what would you apply in practice?	Open question
What are (possible) barriers to applying what you learned to your company?	Open question

For the place-based series, we included a short evaluation round at the end of each masterclass, based on which the next masterclass was planned. However, since the process in BKV will continue in the second series of masterclasses, the process is in a too early stage to have a more in-depth evaluation of process outcomes.

Results and discussion

Masterclasses as a valuable learning approach?

According to the questionnaires completed after the general masterclasses, the sessions were considered as either very useful or useful (45.5% and 42.5%, respectively), only one participant indicated that one of the sessions within a masterclass was not useful (0.4%). Elements which participants considered as most interesting included i) a good balance between theory and practice and the strong link between both, ii) the opportunities for hands-on practice (especially during the pruning masterclasses), iii) the focus on practice through e.g. farm walks and field visits, iv) having open and realistic testimonies of people with years of AF experience, and v) the contacts made with not only the experts, but also the other participants. While the first three are more related to the educational methods, with opportunities for practical experience, the latter two specifically refer more to the networking aspect, and peer-to-peer learning opportunities. When discussing the value of the masterclasses during the focus group, the networking aspect became even more prominent. Several participants considered this as the most valuable aspect of the masterclasses, and indicated that they had broadened their network significantly, and also had contact with participants outside of the masterclass programme. Participants had more problems indicating what they had learned specifically from the different masterclasses, and indicated that some of the topics lacked sufficient depth, and that they still need more information, to steer their decision making. This is also in line with results from the questionnaires, where the majority of participants indicated that they considered applying what they learned in the masterclass in practice (78% yes, 18% maybe), but still experience barriers to the actual application. Main recurring barriers that were mentioned were legislative and regulatory aspects, insufficient knowledge available, and insecurity about financial return (also linked to scale). Finally, as also indicated in the questionnaires, the combination of theory and practice was crucial for most participants, and wanted to see this expanded in the second series. The importance of having a specific hands-on exercise as part of the overall learning experience was highlighted by one of the participants: *"the combination of the theory, followed by the opportunity to apply that theory immediately afterwards in practice, gives me sufficient confidence to also apply this back home"*. However, including hands-on experiences in the interactive sessions of the masterclasses was not always straightforward. In some cases, the topic was not entirely suitable (e.g. food forests), but also the group size was often a limiting factor. While we limited the number of participants, some participants indicated that an even smaller group could have been beneficial. The importance of group size was also emphasized by Marchand et al. (2019), in the context of on-farm demonstrations, and should be carefully considered for the second series.

So far, the evaluation approach we followed mainly focuses on the short term effect of participating in the masterclasses. Such a short-term evaluation tends to focus more on what participants take home after the masterclass, and does not assess what participants do with what they take home. The focus group close to the end of the first series tried to tackle this to some extent, but still the time lag is relatively short, especially considering the complexity of decisions that need to be made in some cases, and the influence of other factors on the decision-making process (e.g. Edwards-Jones, 2006; Fountas et al., 2006). The value creation framework, developed by Wenger et al. (2011), which distinguishes 5 cycles of value creation – i) *immediate* value considers that networking activities and interactions have value of themselves; ii) *potential* value refers to 'knowledge capital', whose value lies in its potential to be realized late; iii) *applied* value refers to the adoption and application of the knowledge, practices and results learned in one's personal life or professional context; iv) *realized* value goes further than only application. It looks at the effects and successes of the novel practices, both for farmers and other stakeholders; and v) *reframing* value reflects on changed understandings, strategies or goals and changes in the definition of what matters, at individual, collective and organizational level – could be useful to assess this in more detail.

Finally, we would like to emphasise the value of the exploratory masterclasses and the pre-event registration in guiding the overall masterclass programme. While we have to deliver approx. one MC per month, at the same time it was expected that they were demand-driven. The exploratory masterclasses allowed to consider more in general the end-user needs, while more specific questions and considerations were captured by the pre-event registration.

Masterclasses to increase AF implementation?

We believe that the masterclasses have the potential to contribute to the pathways for AF in Flanders, as proposed by Borremans et al. (2018) in several ways.

First, there is the development pathway on education and organization, addressing the limited knowledge of farmers and the agricultural sector in general of AF. Borremans et al. (2018) proposed the following actions for this pathway: (1) to coach teachers in education of agroecology and agroecological competences to introduce AF in the formal education; (2) to create learning networks of farmers on the practical aspects related to AF; (3) to create an action plan for AF development in Flanders that defines where and in which contexts AF systems can deliver maximal benefits and minimal drawbacks. The general series of masterclasses feed directly into the second action, which seems to be confirmed by the preliminary evaluation results of the general series. Also the place-based series have the potential to contribute to this pathway, in line with action 3, although on a smaller spatial scale, however it is too early to assess at this stage in the process.

Second, we also believe that the masterclass series have the potential to contribute to the pathways on social and behavioural aspects, and the creation of an enabling institutional and policy environment. The first pathway reflects on the different discourses, and how the more dominant neoliberal-productivist discourse, held by for instance farmer organisations or colleagues can act as a barrier for AF implementation. Possible actions for this pathway included (1) the facilitation of communication between farmers and extension agents, and between farmers and AF pioneers, and (2) the connection of local authorities, farmers, landowners and local residents around specific topics (Borremans et al., 2018). By inviting AF pioneers to share their experiences during the general masterclass series, we potentially facilitate the first action, however with two important restrictions. First, considering the format, this is done only on a relatively small scale. Second, most participants of the general masterclass series do not follow the dominant discourse, but have a critical view towards it. Considering this, the impact of the general series may be rather limited. The place-based series is a good example of the second action, but again it is too early to assess in this stage of the process

Finally, there are the development pathways of science and technology, and market and finances. The first one advocates a.o. for more participative and transdisciplinary research projects, of which the FarmLIFE project as a whole is a good example. The pathway on market and finances focuses on economic instruments that allow AF to be a more profitable option for farmers. While masterclasses often focused on the economic aspect of AF, we have no intention to develop specific economic instruments for increased AF farm profitability, and as such little impact is expected regarding this aspect.

Conclusion

To conclude, evaluation results so far suggest the masterclass approach has merit, especially regarding the aspect of network formation, and thus shows potential for overcoming some of the barriers for AF implementation in Flanders. It is important to highlight in this respect that FarmLIFE is just one of various other projects on AF in Flanders, and it could be relevant to assess the complementarity of these projects in their contribution to the development pathways identified by Borremans et al. (2018).

Furthermore, we think it is necessary to include an additional evaluation step at a later stage, once the full series of masterclasses has been finalised (expected June 2021), separately for the general and place-based series, to allow for a more extended time lag. The evaluation could focus specifically on two main aspects: i) the development pathways, to assess more in detail if and how both the general and place-based masterclass series have contributed to them; ii) the value that was created in the different networks put in place, guided by the value creation framework proposed by Wenger et al. (2011) for CoPs, incorporating more clearly aspects of knowledge sharing and competency development.

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PHOTOVOICE: A RESEARCH METHOD FOR FARMER-DRIVEN KNOWLEDGE PRODUCTION

Lisette Tara Phelan[a], Simon Ndungu Nyokabi[b], Amanda Berlan[c]

[a] De Montfort University
[b] Wageningen University and Research
[c] De Montfort University

Abstract

This paper argues that there is an imperative for researchers and agriculture sector stakeholders to adopt research methods that place smallholder farmers at the centre of knowledge-creation processes. Although they are custodians of local agricultural and environmental knowledge systems, farmers are often not considered to be part of the 'community of practice' when it comes to enhancing the sustainability of agricultural production systems. Using cocoa farmers in Ghana as a case study, this paper demonstrates that Photovoice is a useful research method for co-generation of knowledge in the context of climate change adaptation and mitigation.

Photovoice recognises that farmers are producers of knowledge and is a method that does not look to prescribe what knowledge farmers should capture, or how they should present it. In the context of this case study, photovoice was used to elicit information on the impact of climate change on cocoa production and farmers' livelihood security. Farmers selected to participate in the study were provided with integrated flash-equipped disposable single-use cameras, brief instructions on how to operate the cameras, and asked to go to their farms to capture and communicate their lived experience of climate change through the medium of photography.

Farmers were enthusiastic in sharing why they captured a particular image or a series of related images, during a subsequent feedback session. Recognising that 'a picture is worth a thousand words', many of the farmers entrusted with cameras reported that they had allowed neighbours to also take photographs on their farms. They justified doing so by stating that if the objective was to gain insight into the impact of climate change on cocoa production and farmers' livelihood security, then it should capture the diversity of lived experiences. Moreover, they argued, if the exercise was farmer-led, they should be allowed to adapt the research method to suit their circumstances.

Photovoice increases farmers' agency in knowledge-creation processes. As it can provide insight into the impact of climate change on agricultural production and livelihood security in a way that allows farmers to shape their own narrative, photovoice is a powerful tool for researchers and agricultural stakeholders interested in identifying opportunities for intervention in the arena of climate change adaptation and mitigation.

Introduction

Smallholder farmers have a wealth of agricultural and environmental knowledge. Acquired through lived experience and experimentation, however, it is implicit rather than explicit knowledge, embedded in practices, processes, routines and norms (Bolisani and Bratianu, 2018; Girard, 2015; Stuiver et al., 2004; Tress et al., 2007). Reflecting local and historical availability of socio-material resources, and resource allocation or use under conditions of uncertainty, farmers' knowledge is action-oriented or procedural and constitutes a combination of skills or know-how, derived from a learning process which involves continuous re-interpretation and evaluation of situational information accumulated. This process is stimulated by farmers' interaction with their natural and social environment during engagement in regular and/or experimental production-related activities (Bolisani and Bratianu, 2018; Stuiver et al., 2004). Farmers monitor and evaluate decisions and adjust production practices to account for contingencies and in response to unintended effects; they learn by doing and do through learning (Goulet, 2013; Stuiver et al., 2004).

Although they are custodians of local agricultural and environmental knowledge systems, smallholder farmers are often not considered to be part of the 'community of practice' when it comes to enhancing the sustainability of agricultural production systems (Magni, 2017; Raymond et al., 2010). Scientific or technological knowledge and expertise are instead given primacy in debates over sustainability, as are technocratic interpretations of sustainability (Feola, 2015; Van Assche et al., 2017). Scientific or technological knowledge is reductionist, however, and does not encourage communities of practice to take a holistic view towards realising the sustainability of agricultural production systems, which are essentially complex social-ecological systems (Fischer et al., 2015; Girard, 2015; Stuiver et al., 2004). As farmers' knowledge recognises complexity, it constitutes a useful resource in understanding how ecosystems can and cannot be transformed and managed, and social systems can be designed to better fit with ecosystems (Stuiver et al., 2004).

Social-ecological sustainability can only be realised through transformational change (Fischer et al., 2015; Termeer et al., 2017). Knowledge that is useful for transformational policy-making can only emerge where conflict between expert and stakeholder knowledge is encouraged and the knowledge creation process involves facts, interpretations, assumptions and causal relations from different knowledge domains being exchanged, combined and harmonized (Bathelt et al., 2004; Buuren and Edelenbos, 2004; Edelenbos et al., 2011; Girard, 2015). If debates on sustainability are underpinned by scientific or technological knowledge alone, it can result in the sustainability of a social-ecological system being undermined rather than enhanced (Smith and Stirling, 2008; Stuiver et al., 2004). The incorporation of farmers' knowledge in debates on sustainability increases the likelihood that resultant intervention strategies are not only scientifically valid, but also, socially valid, and therefore, importantly, do not maintain the status quo at the expense of transformational change (Folke et al., 2010; O'Brien and Sygna, 2013; Pelling, 2011; Termeer et al., 2017).

Photovoice is a community-based, participatory visual research method which initiates a knowledge-creation processes which not only contributes towards fostering critical dialogue between stakeholders with an interest in enhancing the sustainability of agricultural production systems against a backdrop of climate change, through adaptation and mitigation; but importantly, as it is inclusive of smallholder farmers' perspectives on sustainability, it can generate knowledge which is socially valid and thus useful for policy-making. Recognising the need to incorporate knowledge produced outside the formal systems of agricultural research and development into debates on sustainability, this paper outlines how Photovoice can be used to capture and transform farmers' implicit knowledge into explicit knowledge. Using cocoa farmers in a small community in Bodi District, Western North Region, Ghana as a case study, this paper explores farmers' perceptions of the impacts of climate change, and soil- and water-related challenges faced in pursuing cocoa production as a livelihood strategy; and farmers' adaptation and adoption of coping strategies, and factors constraining their adaptation and adoption. In addition, the paper discusses the limitations of the method, and the extent to which farmers can be empowered during and as a result of a Photovoice-based research process.

The Photovoice Method

Photovoice is a research method which is underpinned by feminist and critical consciousness theory, and the principles of participatory documentary photography (Novak, 2010). It aims to engage individuals and communities as active rather than as passive participants in exploring lived experiences, and documenting and analysing socio-ecological phenomena (Cook, 2015; Cook et al., 2016; Liebenberg, 2018). Recognising that there is a need to address the power imbalances which have traditionally existed between researchers and research participants, Photovoice takes into consideration historical, economic and political structures responsible for the marginalisation and oppression (Liebenberg, 2018). It looks to demystifying contexts and structures which maintain oppression, and revealing how assumptions and behaviour lead to oppressive systems being maintained (Plunkett et al., 2013; Sanon et al., 2014). Premised on the idea that research participants should determine the research focus, be involved in the data collection and analysis process and sharing of findings (Liebenberg, 2018); Photovoice engages marginalized individuals and communities throughout the research processes.

Recognising the interplay between knowledge creation and agency (Suffla et al., 2012), one of the main objectives of Photovoice is to promote social justice and empower. Encouraging research participants to assert their voice and their capacity for sense-making, knowledge-creation and knowledge-management (Nonaka and Toyama, 2015), the research method encourages research participants to contest their marginalization and exclusion from mainstream discourse, policy debates and interventions (Girard, 2015; Stuiver et al., 2004). As socially-acceptable, context-specific solutions to issues can only be identified where individuals are self-aware, willing to leverage their social capital, and advocate for their own and their community's well-being (Hergenrather, Rhodes, Cowan, Bardhoshi, & Pula, 2009; Wang and Burris, 1997); Photovoice encourages research participants to engage in collective reflection, introspection and discussion.

Similar to other visual research methods such as photo-interviewing, photo-elicitation and reflexive photography, Photovoice encourages individuals to communicate their story through the medium of photography, and does not prescribe what photographs should be captured, or how photographs should be presented (Leung et al., 2017). Detecting issues that would likely remain hidden if a top-down, quantitative rather than bottom-up, qualitative approach was taken to data collection (Wang and Burris 1997; Wang, 1999; Budig et al., 2018; Cook, Brown, & Ballard, 2016), Photovoice constitutes a research tool that can be used by researchers to explore the social, economic and/or environmental issues undermining sustainability of complex social-ecological systems, and therefore, adversely impacting research participants' everyday lives (Budig et al., 2018; Jaiswal et al., 2016; Leung et al., 2017).

Although Photovoice emerged from and was initially used primarily in the context of public health research, it is today used in many other research disciplines (Budig et al., 2018; Jaiswal et al., 2016; Leung et al., 2017). There are, however, still only a handful of studies relating to agriculture and climate change. Notably, Photovoice has been used to asses ecosystem services and human wellbeing in Costa Rica (Berbés-Blázquez, 2011); to determine social and environmental change in coastal communities in Thailand (Bennett and Dearden, 2013); to understand social constructions of climate change and rising sea levels (Baldwin and Chandler 2016); to examine water use and needs in Western Kenya (Martin, 2019); enhancing female farmers' active participation in agricultural development programmes (Gervais and Rivard, 2013); and to explore perceptions of climate change in small family farms in the USA (Bulla and Steelman, 2016).

As far as we are aware, this is the first study that uses Photovoice to explore smallholder farmers' perception of the impacts of climate change on cocoa production, and specifically, the soil- and water-related challenges which farm households and communities face in pursuing cocoa production as a livelihood strategy. This study, therefore, contributes to addressing the current gap as regards the use of participatory visual research methods such as Photovoice in the context of the research discipline, which is cocoa research, but also contributes to extending the use of the research method to farmer-driven research relating to the management of soil and water resources.

Methods

2.1. Study location

The case study outlined in this paper stems from the results of a larger study focusing on soil and water management in cocoa production systems, which involved the use of a wide range of qualitative research methods over a period of six months of fieldwork (April-September 2018) in the cocoa-producing regions of Brong Ahafo, Western North and Central Region of Ghana. Ethical clearance for this study was obtained from De Montfort University prior to the start of the study. The Photovoice component of the study took approximately two months to complete (July-August 2018) and involved providing farmers in Bodi District, Western North Region with disposable single-use cameras so that they could capture their lived experience of producing cocoa against a backdrop of climate change. The study location was chosen due to the importance of cocoa production, farmers' enthusiasm to voluntarily participate in the study, and COCOBOD's willingness to provide logistical support in reaching out to the community.

2.2. Sampling strategy

A purposive sampling strategy was used to select farmers for the Photovoice component of the prior mentioned larger study which looked specifically to explore to what extent farmers' perception of climate change, and their knowledge relating to soil and water management could be key to enhancing the sustainability of cocoa production systems, against a backdrop of climate change. This choice of sampling strategy ensured that farmers who took part in the study were: (a) cocoa farmers; (b) had lived in the area/region for more than one year; (c) were willing to learn how to use a disposable single-use camera; (d) agreed to voluntarily participate in the initial group session to learn how to use the camera and receive instructions as regards undertaking the Photovoice activity; and (e) agreed to participate in a follow-up, afternoon-long group session where the pictures taken would be categorized, discussed to elucidate their meaning and significance, and a final selection of photographs made.

2.3. Photovoice procedure

A meeting was organised with the help of the COCOBOD extension officer responsible for providing extension to the community. A total of 15 disposable single-use cameras were provided by the researcher for use by the farmers who agreed to participate in the study, with cameras distributed on a first-come-first-served basis. As a large number of farmers expressed their interest in participating in the study, farmers who had a phone with a camera were encouraged to take part, using their phones to capture images which could then be copied or sent to the researcher's phone to allow for their printing and inclusion in the follow-up group discussion. Farmers who did not have a smartphone, or the capacity to take a photograph using their smartphone, were prioritised in the distribution of cameras. In total, 38 farmers participated in the study: 8 farmers used their smartphones and 15 farmers used disposable single-use cameras. The latter group of farmers shared the cameras received with an additional 14 farmers (i.e. neighbours, friends and family) who also wanted to participate in the study.

The concept behind Photovoice - as outlined by Wang and Burris (1997), Novak (2010) and Bennett and Dearden (2013) - was explained to the 5 female and 19 male farmers who were present at the initial one-hour long group session and agreed to participate in the study. Farmers were informed that - unlike a paper-based survey or an interview involving the use of a dictaphone and note-taking materials, where the research was in charge - they would be responsible for the data collection process. Moreover, they were informed that the objective of Photovoice was to give them the opportunity to influence the research process and the process by which knowledge is created, captured and used, in this case by collecting visual data. The ethics of taking photographs was explained and discussed, and farmers who agreed to participate in the study were asked to give their consent for photographs taken to be used in the follow-up group discussion, and in the larger study focusing on soil and water management in cocoa production systems.

Farmers were instructed to take photographs over a two-week period, while or after undertaking regular day-to-day activities on their farms. They were shown how to use the disposable single-use cameras during the initial one-hour long group session. Although each camera was equipped with an integrated flash and its use was demonstrated, farmers were encouraged to take photographs during daylight hours rather than during low light conditions (i.e. at dusk or dawn), to ensure that the exposure would be adequate, given the fixed aperture and shutter speed of the cameras. Farmers were reassured, however, that it was not a problem if they wanted, for a particular reason, to take a photograph in the early morning or early evening (as long as the integrated flash was used). To verify that farmers understood how to use the cameras, a self-appointed leader of the group of the 23 farmers was invited by the researcher to take a photograph of the group and asked to assist farmers who subsequently faced difficulties in taking photographs on their farms.

The aims and objectives of the Photovoice exercise were explained, and farmers were given the opportunity to raise questions as regards the process. Farmers were asked to communicate their perception of the impacts of climate change, and the soil- and water-related challenges faced in pursuing cocoa production as a livelihood strategy. They were informed that it was not a problem if the disposable single-use camera was used to take photographs on multiple farms and/or by more than one farmer, given the interest in taking part in the study. Moreover, they were informed that there was a limit, however, as to how many photographs could be taken with the cameras, with each camera having the capacity to take a maximum of 27 pictures only. Finally, they were informed that it was necessary to take the photographs within the agreed two-week period as the cameras would have to be collected by the COCOBOD officer on behalf of the researcher, so that the film-roll could be sent away for development and the photographs printed in anticipation of the follow-up group discussion.

2.4 Participatory data analysis

This study followed guidelines outlined by Wang and Burris (1997), Novak (2010) and Bennett and Dearden (2013) as regards ensuring that the analysis of the data (i.e. photographs) collected by farmers was undertaken in a participatory manner. As the analysis was undertaken in an outdoor environment, farmers were asked to arrange photographs based on their similarity to other photographs (i.e. thematically) on A3-size paper sheets laid out and weighed down with stones, to reduce the likelihood of water damage. This arrangement of the photographs enabled farmers to more easily follow the three-stage process of (a) selecting the photographs that they felt most accurately reflected their individual and collective lived experience in producing cocoa against a backdrop of climate change; (b) contextualising the photographs by providing an explanation or reason as to why specific photographs relating to the impacts of climate change on production were taken, to determine their meaning and significance in the context of the individual and collective lived experience; and (c) codifying the photographs by identifying emergent issues, themes and/or theories. At the end of the group discussion, the 38 farmers who took part in the Photovoice exercise were asked to choose a final set of 20 photographs and state by means of a single sentence (i.e. a caption) what message they wanted to convey to the researcher and/or policy-makers.

Results

The farmers who received the disposable single-use cameras took a total of 405 photographs, as each camera had the capacity to take 27 photographs. Of the total the 405 photographs developed for use in the follow-up group discussion developed, farmers selected to use 105 photographs which they judged to be in-focus and correctly-exposed based on training given prior to the photo-taking exercise. The farmers who used their smartphones to take photographs took fewer out-of-focus and under- and overexposed photographs. Consequently, 50 of the photographs which they shared with the researcher were also printed for use in the follow-up group discussion. This resulted in a total of 155 photographs being discussed by farmers during the follow-up group discussion held over the course of an afternoon, approximately a month-and-a-half after the photographs were taken.

Farmers were enthusiastic about sharing why they captured a particular image or a series of related images during the follow-up group discussion. Recognising that *'a picture is worth a thousand words'*, many farmers remarked that they had allowed neighbour farmers, with whom they shared boundaries, to use the disposable single-use cameras to take photographs on their farms. They justified doing so by stating that if the objective was to gain insight into the impact of their and the community's climate change on cocoa production and farmers' livelihood security, then it should capture the diversity of lived experiences.

Using the photographs taken as a starting point for discussion, farmers determined that climate change impacted on cocoa production by influencing pest and disease incidence, drought stress in cocoa trees as reduced soil water availability undermined soil fertility and uptake of nutrients, and/or inducing flooding stress as excess soil water led to soil waterlogging, erosion and reduced soil fertility and uptake of nutrients. This led farmers to conclude that it was necessary to plant economic trees (while at the same time, regulating the level of shade provided by cutting), and respond to the impact of tree death by planting alternative food crops to compensate for income foregone, and/or plant food crops providing temporary shade below which cocoa seedlings could be established. Moreover, it was important to regulate competition for water and nutrients, by removing crops and non-economic trees competing with cocoa trees and controlling weed growth. Finally, it was important to efficiently use available water resources (for spraying, drinking and cooking) during periods of reduced water availability, and conversely, manage the impact of excess water during the rainy season which resulted in soils becoming waterlogged and/or eroded by water movement, and therefore, less fertile.

Insect pest and disease incidence

Farmers reported that insect pest and disease incidence was influenced by the weather patterns, with higher incidence observed during the rainy season compared to the dry season. The majority of farmers stated that they found it difficult to control insect pests such as akate (mirids) and atee (stink bugs) (**Figure 1)**, and were worried about the impact of black pod disease (*Phytophthora spp.*) on yields (**Figure 2**).

Figures 1 and 2 (from L to R): Pod damage caused by akate (mirids) and/or atee (stink bugs) and black pod disease (Phytophthora spp.)

Drought stress

Farmers reported that one of the biggest impacts of a change in the rainfall pattern and the duration and intensity of the dry season, was that their cocoa trees were subject to drought stress. They noted indicators of drought stress: a change in leaf colour (from dark green to yellow and red), reduced pod production, dieback (i.e. death of twigs and branches) and leaf loss, and ultimately, tree death (**Figures 3** and **4**).

Figures 3 and 4 (from L to R): Indicators of drought stress - leaf colour change, dieback and leaf loss

Observing that cocoa tree death led to a canopy gap and the creation of clearings (i.e. large empty spaces) (**Figure 5**), farmers explained that, in some cases, they tried to re-establish cocoa seedlings and in other cases, they planted crops other than cocoa in the clearings on their farms.

Figures 5: Tree death resulting in a canopy gap and the creation of clearing

Importance of shade

Farmers reported that it was important to plant economic trees (**Figure 6**) - such as emere (*Terminalia ivorensis*), ofram (*Terminalia superba*), odum (*Milicia excelsa*) - which could provide shade for their cocoa trees.

Figures 6: Economic trees providing shade for cocoa trees

Importance of regulating competition for water and nutrients

Farmers observed that it was important to regulate the availability of water and nutrients in the soil by removing competing crops (i.e. oil palm) and controlling weeds (**Figures 7** and **8**).

Figures 7 and 8 (from L to R): Oil palm trees and weeds competing for water and nutrient resources

Impact of climate change on soils

Farmers observed that climate change was impacting the quality of the soils on their farms, particularly where cocoa trees had died and the soil was not protected from the 'harsh' sunshine (**Figure 9**) by the canopy of the cocoa and economic trees, food crops or a layer of leaf litter.

Figures 9: 'Harsh' sunshine directly hitting soil surface

Importance of water

Farmers explained that they had taken photographs of rivers and streams passing through their farms to communicate the importance and benefits of having access to a source of water for chemical application (i.e. spraying pesticides, fungicides and herbicides) and household use (i.e. cooking and drinking), particularly during the dry season (**Figure 10**).

Figures 10: Streams provide water for spraying, cooking and drinking

Soil erosion and flooding stress

Finally, farmers reported that they had taken photographs to communicate the impact of heavy and/or continuous rainfall, particularly during the rainy season, and the extent to which water movement led to soil erosion (**Figure 11**) and impacted on soil fertility, and flood events resulted in soils becoming compacted and/or waterlogged (**Figure 12**).

Figures 11 and 12 (from L to R): Impact on soils of erosion due to water movement and waterlogging

As a consequence of the limited time and resources allocated to the researchers in undertaking this study, it was not possible to organise a photo exhibition. The final stage of the research process – translating and disseminating knowledge to policy-makers – is scheduled to take place at a later date; as noted earlier, the case study outlined by this paper is part of larger, still ongoing, study focusing on soil and water management in cocoa production systems.

Discussion

The results of this study indicate that smallholder farmers are aware of climate change and its adverse impact on cocoa production, by way of its impact on soil and water resources. This knowledge led farmers to adapt and adopt coping strategies to control pest and disease incidence, drought stress, competition for water and nutrients, flood stress, soil waterlogging and erosion, and enhance soil fertility. By planting seedlings to replace mature trees that had died, while ensuring that their mature trees remained productive, farmers sought to manage both the short- and long-term impacts of climate change. They also planted alternative food crops to compensate for income foregone as a result of tree death and replanting.

The study findings are in agreement with previous studies which explored cocoa farmers' knowledge and coping strategies relating to climate change and its impacts on cocoa production, such as Codjoe *et al.* (2013) and Ehiakpor, Danso-Abbeam and Baah (2016), soil fertility management (Dawoe et al., 2012), the benefits of producing cocoa under agroforestry conditions (Isaac, Dawoe and Sieciechowicz, 2009) and selecting appropriate shade tree species for incorporation in production systems (Anglaaere et al., 2011; Graefe et al., 2017), and perceptions of mirid control and willingness to use forecasting systems (Awudzi et al., 2016). Although these studies involved researchers adopting a quantitative, qualitative or mixed methods approaches to data collection, they were not necessarily conducted in a farmer-led, participatory manner.

Moreover, the study findings reveal that farmers appreciate being given the opportunity by the researchers to share their agricultural and environmental knowledge with the wider 'community of practice' focused on enhancing the sustainability of agricultural production systems against a backdrop of climate change. Similar to the findings of Beilin (2005) and Kong et al. (2015), this study confirms that individuals feel empowered when asked to document and explain their lived experience using a community-based, participatory visual research method such as Photovoice, and that they are willing to reveal their relationships to the natural and social environments in which they are operating. The farmers who participated in this study critically reflected on the photographs taken and their meaning, and were at ease sharing their perceptions of climate change and knowledge relating to the management of soil and water resources. Aware that they were in the position to drive the data collection, analysis and resultant knowledge-creation process, they felt ownership over data collected.

The study findings indicate that individuals are positively influenced to engage in research which employs a community-based, participatory visual research methods such as Photovoice, similar to Kong et al. (2015). It is worth noting, however, that Photovoice - like all research methods - has its limitations, as outlined in detail by Novak (2010). Firstly, where integrated flash-equipped disposable single-use cameras are used, it is a method which can be logistically challenging to implement. There are few printing shops which offer to develop film-roll, particularly in transitioning countries such as Ghana, and the method thus relies on the researcher being able to travel from rural areas where the research is undertaken, to larger cities to develop and print the photographs. It would be preferable to use digital cameras; however, this would increase the cost of undertaking the research. Moreover, the use of digital cameras would necessitate more training to avoid influencing farmers' actions and the research process, as reported by Änggård (2015). Secondly, the extent to which Photovoice promotes social justice and empowers research participants is entirely contingent on the involvement of individuals and communities throughout the research process (Johnston, 2016). In the case of this study, while farmers were involved in determining the research focus, and in the process by which data was collected and analysed, they were not involved in the sharing of findings in a research environment beyond the follow-up group discussion (i.e. a photo exhibition). Farmers' only engagement with stakeholders beyond their community was with COCOBOD extension officers who were present during the initial and follow-up group discussions. Consequently, the objective of 'giving voice' to farmers and enhancing their empowerment as individuals and as a community through the use of the Photovoice method was only partially realised.

Conclusion

This paper has outlined the case for researchers and agriculture sector stakeholders to adopt research methods which place smallholder farmers at the centre of knowledge-creation processes. Using cocoa farmers in Ghana as a case study, it has highlighted the extent to which community-based, participatory visual research methods increase farmers' agency, and provides insight into the impact of climate change on agricultural production and livelihood security in a way that allows farmers to shape their own narrative. Photovoice is a powerful tool which allows farmers' perspectives and knowledge to be captured, incorporated and shared within a 'community of practice' focused on enhancing the sustainability of agricultural production systems against a backdrop of climate change. Bringing scientists and farmers together to form a more inclusive 'community of practice', Photovoice increases the likelihood that knowledge that emerges from research is not only useful for policy-making, but ensures that resultant intervention strategies are scientifically valid, socially valid, and do not maintain the status quo at the expense of transformational change.

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ON-FARM DEMONSTRATION AS A POTENTIAL PEER LEARNING AND TACTILE SPACE TO FOSTER SUSTAINABLE AGRICULTURE: A VIDEO STUDY

Cooreman Hanne[a], Vandenabeele Joke[b], Debruyne Lies[c], Marchand Fleur[d]

[a]KU Leuven & Social Sciences Unit, Institute for Agricultural and Fisheries Research (EV ILVO), Belgium.
[b]KU Leuven - Laboratory for Education and Society, Belgium.
[c]Social Sciences Unit, Institute for Agricultural and Fisheries Research (EV ILVO), Belgium.
[d]University of Antwerp, Ecosystem Management Research Group and IMDO.

Abstract

Tactile spaces, based on Carolan (2007), as learning environments are assumed to have the potential to raise rate of adoption of innovative agricultural and environmental practices. They influence individuals' attitudes through social embeddedness or interconnections among people, and physical embodiedness or physical negotiations with environmental surroundings. Learning in a tactile space requires that individuals can use all their senses to assimilate their surroundings, and thus to construct and convey not only representational knowledge, but also nonrepresentational knowledge. Such learning environments advocate a more participatory and experiential manner than top-down transfer of technology approaches. Through reflecting upon on-farm demonstrations as potential tactile spaces, we aim to gain clarifying insights in how learning processes and outcomes take place when attendees of on-farm demonstrations interact with the environment the on-farm demonstration offers, including other attendees.

To investigate on-farm demonstrations as tactile spaces and places for peer learning, we introduced video analysis as a part of a mixed methods approach. We developed a new video guideline for analysis as a set of targeted video shots related to learning activities, communication initiation and interactive knowledge creation, and to concepts underlying a tactile space, physical embodiedness and social embeddedness. We complemented this video analysis with post demonstration surveys and longitudinal telephone interviews to grasp farmers' reflection and adoption processes.

We reflect upon this methodology through the lens of one Belgian on-farm demonstration on mechanical weed control as a potential tactile space.

We found that farmers reflected and thought actively about opportunities for their specific situation through attending this OFD. Prices of the demonstrated machines seemed to be the biggest barrier for adoption. Farmers also seemed to think actively about alternatives as for example found in contract workers, working together and sharing a machine, and changing parts of the machines. This study also resulted in suggestions for amelioration of both the video analysis guidelines as the telephone interviews. In addition we formulated suggestions for further research investigating what triggers reflection and learning: 1) the need for formally organised discussions and 2) organising OFDs which elaborate on physical experiences both in amount of time, deliberate organisation and variation.

Overall, our study shows that with some enhancements, this mixed methods approach seems promising to grasp an OFD as a tactile and peer learning space triggering reflection, a first step in deciding on adoption. Additionally this method assists in defining strengths and weaknesses of an OFD in terms of aplied learning activities. We conclude that more research is needed, but we suggest it is beneficial to organise OFDs more as tactile and peer learning spaces to foster sustainable agriculture, using its' potential as a rich learning environment more effectively.

Introduction

Our fast changing context, characterised by climate change, the need to address complex, often local, problems related to sustainable resource management, and the globalised markets based on technology and knowledge, has initiated a more complex system of knowledge exchange compared with the past (Swanson, 2010). Therefore, to address these complex challenges related to the aspiration of a more sustainable future, innovation should be more 'co-produced' through interactions between all stakeholders (EU SCAR, 2012). Participatory, more bottom-up approaches in agricultural extension, represent this recent trend, associated with a number of benefits including higher rates of adoption and practice change, positive effects on yield, income and productivity; greater well-being, increased knowledge and skills associated with empowerment; and the availability of peer support (Davis et al., 2012; Ingram et al., 2018; Prager & Creaney, 2017; Swanson, 2010).

We argue that on-farm demonstrations (OFDs) as an agricultural knowledge exchange activity (Leeuwis & Van den Ban, 2004) fit well in this shift in approach towards more participatory agricultural education activities. We define an OFD, based on the interpretation found in the analytical framework of the recently finished AgriDemo-F2F project (2017-2019; Koutsouris et al., 2017; Burton et al., 2017 (related PLAID project)): as a demonstration activity for providing farmers with "an explanation, display, illustration, or experiment showing how something works" (Collins English Dictionary). OFDs take place preferably on actual working farms so the demonstration can be visualised in real life conditions. OFDs can thus provide the opportunity for farmers to physically gather, discuss together with both peers and experts, jointly solve problems, monitor experiments, observe and compare practices in similar contexts to their own, as well as experience hands-on activities (Ingram et al., 2018). Therefor it is not surprising that OFDs have become an established practice in a number of advisory and extension systems (Vanclay, 2004). It's a versatile practice that can be used for a great variety of advisory and extension strategies (e.g. supporting horizontal knowledge exchange; generation of policy and/or technological innovations; and supporting organisation development) and functions (raising awareness and consciousness; exploration of views and issues; communication on innovations) (Leeuwis, 2004). Another reason for our focus on OFDs are the multiple studies confirming demonstrations as a preferred way to learn by farmers. Franz, Piercy, Donaldson, Westbrook, & Richard (2009) for example summarised the most preferred learning methods by farmers, of which the first five were: hands-on, demonstration, farm visit, field day and discussion. We believe that OFDs as learning spaces have the potential to combine multiple of these preferred methods, for example by including hands-on activities and discussion sessions during an OFD.

In this paper, we aim to go beyond studying only interactions between people by also articulating influences of the environmental surroundings an OFD can offer. The relevance of the introducing the concept of 'tactile space' for our objectives we found in a statement made by Cowan et al. (Cowan, Goldberger, Miles, & Inglis, 2015): 'Tactile spaces can serve as participatory, experiential, and compelling counterpoints to traditional "top-down" approaches to diffusing information about innovative agricultural and practices.'

In his primary writings on tactile space, Carolan (2007) who introduced the concept does not mention the classic diffusion-of-innovations model (Rogers, 2003), a longstanding well-known model in research on adoption and diffusion of innovation in agriculture. However, these two approaches overlap in noteworthy ways (Carolan, 2016), confirming even more the relevance of this concept for our research. First, both emphasize the importance of interpersonal communication channels and social networks. Second, both acknowledge the importance of physical engagement with one's surroundings. Third, both argue that interpersonal relationships and physical engagement can change individuals' attitudes about new technologies, practices, and ideas. Thus, one can conclude that tactile spaces have the potential to influence the rate of adoption of an innovation.

The concept of 'tactile space' refers not simply to a space for seeing and/or touching, as a literal interpretation of the term 'tactile' might suggest. Rather, it influence individuals' attitudes about new technologies, practices, and ideas through both 'embeddedness and embodiedness'. Thus, it involves interconnections among people (i.e., social embeddedness) and physical negotiations with environmental surroundings (i.e., physical embodiedness). This implicates that individuals can see, taste, touch, smell and hear for themselves the phenomena around which knowledge claims and constructs are made (Carolan, 2007). This goes beyond learning of representational knowledge, but stimulates the learning of nonrepresentational knowledge (an embodied, or practice-based, learning, wherein the knowledge obtained is not represented easily through language only, but involves assimilating stimuli through the use of multiple senses) (Cowan et al.,2015). Carolan (2007) says that those involved in these spaces are encouraged to see problems as more than mere 'puzzles' which can be resolved through quick technological fixes. This nurtures a systemic view, where connections are highlighted between people, social structures, and the environment. According to our point of view, this could be a stimulating and effective way to learn about wicked problems encountered through striving for more sustainable agriculture.

A relevant practice example is that of a tactile space as a sustainable agriculture field day (Carolan, 2008). In general, agricultural field days bring together "experts" (i.e., agricultural scientists, extension educators,) and farmers on site to engage in not only unidirectional knowledge transfer (expert to farmer) but also knowledge coproduction (Carolan, 2008). Knowledge coproduction by experts and farmers involves the open discussion and debate of knowledge claims. When the physical space (e.g., the field) becomes the physical representation of conveyed knowledge, the space is considered a tactile space. As Carolan (2006b) explains in reference to the field days organised by a sustainable agriculture organisation in Iowa: "those in attendance did not merely stand idly by and absorb information. Rather, they listened, touched, walked through, and discussed the knowledge claims." "Growers could engage the knowledge claims directly, via active engagement in sensuously rich tactile space, and decide for themselves which farming techniques and practices to adopt or not" (Carolan, 2006a). This example demonstrates that agricultural field days, when set up as tactile spaces, can influence the adoption process (Carolan, 2006a). Comparing OFDs with agricultural field days is not a far stretch, since a field day could be a type of OFD.

Showing similarities in underlying conceptual constructs, our previously presented conceptual framework to reflect upon on-farm demonstrations as farmer-to-farmer learning environments for sustainable agriculture (Cooreman et al., 2018) puts forward learning processes of communication initiation by farmers and interactive knowledge creation between all attendees. The importance of for example open discussions but also negotiation of conflictual points of view underlying the core process defined as interactive knowledge creation are already specifically defined learning activities playing a valuable role in contributing to a tactile space. The same is true for activities such as specifically sharing own knowledge and values and formulating questions, which underlies communication initiation in the framework. Therefor we consider these concepts in this research.

A broad range of work in educational sciences has shown that to fully understand how people learn, it is important to look beyond the individual, pointing also to the importance of understanding interactions between individuals and artefacts (Ramey et al., 2016). Therefor we decided to use video as data gathering tool and consequently a comprehensive data source, capturing talk, gaze, gesture, movement, and interactions in a format that is available for repeated viewing. These features make video an ideal source for capturing and analysing context (Ramey et al., 2016), which plays a crucial role in tactile space, communication initiation and interactive knowledge creation.

As a measure of effectiveness of an OFD, we evaluate attendees' reflection and adoption regarding the demonstrated agricultural practices. We ask ourselves the question if and how it would be beneficial for farmers' reflection and adoption to stimulate the design of OFDs as peer learning and tactile spaces, in which participants' experiences and knowledge constructs may be enriched by the environment and those negotiating the environment with them.

Methodology

We used a mixed methods approach to investigate the prevalence of key aspects underlying interactive knowledge creation, communication initiation, physical embodiedness and social embeddedness. As a learning outcome and measure of effectiveness, we aim to investigate attendees' reflection and adoption regarding the demonstrated agricultural practices. Therefore, we complemented the qualitative method of video analysis (a) to grasp the concepts stimulating learning processes with quantitative post demonstration surveys (b) and qualitative longitudinal telephone interviews with attendees (c), conducted about 6 months after the OFD, to grasp the learning outcomes in terms of reflection and adoption.

Materials

Video analysis guideline

We deemed the use of video for data gathering and analysis necessary and appropriate to grasp concepts as physical embodiedness in terms of engaging with different senses with the environment and social embeddedness in terms of interconnections and network building (Carolan, 2007). Therefore, presented as a first data collection source in this research, we developed a video analysis guideline. We added an additional focus on the prevalence of the concepts related to interactive knowledge creation and communication initiation by participants as represented in our previously constructed conceptual framework (Cooreman et al., 2018). Since we knew from our experience in the AgriDemo-project that most OFDs take about half a day, but we did not have any idea on the general focus of an OFD on our elements of interest, we decided to aim for an amount of minutes of video as a starting point. Thereby we kept in mind that the goal of the video analysis guideline is to be generally applicable during OFDs. The use of minutes as metrics is also subject of reflection in this paper. This video analysis guideline was not an official method constructed and utilised in the AgriDemo-F2F project.

Video analysis guideline to conduct during an OFD:

Physical embodiedness, if present focus on for at least 10' video each:

engaging with different senses with the environment (smell, touch, hearing, taste, and sight)

hands-on opportunities

Social embeddedness, if present focus on for at least 10' video each:

interconnections and network building

informal conversations between participants

Enriching peer learning framework, if present focus on for at least 5' video each:

Interactive knowledge creation:

Knowledge scaffolding by the main demonstrator

Open discussion & negotiating conflict

Communication initiation by participants:

Sharing own knowledge; formulating own values

Formulating questions

Post demonstration surveys

The second data collection source used was the post survey for attendees, designed to measure learning processes stimulated by the attended OFD within the AgriDemo-F2F project. We handed out this self-administered survey right after the OFD. This complete survey consisted of four closed questions asking for the answer 'yes' or 'no', 46 closed 4-point ordinal scale questions from 'strongly disagree' to 'strongly agree', with the extra possibilities to answer 'not applicable' and add remarks. Three open questions were also included. To grasp the reflection on implementation and the adoption of agricultural practices, we investigated answers to three 4-point ordinal scale questions: 'I thought about how I could implement some of the ideas and practices on my own farm.'; 'I feel motivated to undertake some sort of action towards sustainable agriculture' and 'I'm thinking about an action I could undertake myself, because of the demonstration.'

Telephone interviews

Approximatly 6 months after the OFD was held, we conducted telephone interviews with OFD attendees. The telephone interviews where designed as a follow-up on the post surveys, also constructed and conducted within the AgriDemo-F2F project. In this paper we will focus on the questions what they learned and what could have made the OFD more interesting for them, to grasp their reflection process. Secondly, to grasp attendees thinking on adoption, we investigate their answers to the question 'Did the demonstration event result in you doing something new or differently (on your farm), or do you plan to change something?' and the answers to the elaborating open questions 'What exactly?' or 'Why not'.

Case description

We gathered data for this paper using the video analysis guideline during a Belgian on-farm demonstration as part of the AgriDemo-F2F project (January 2017- June 2019). This OFD took place on the 8th of June 2018 and focused on mechanical weed control in maize. About eight machines were shown on a part of the maize field of a willing farmer who recently turned to organic production. An advisor guided the demonstration of the different machines by explaining them and showing the difference between them one by one. He let the demonstrators of each machine speak, after introducing them and their machines. Afterwards, there was room and time available for the attendees to have an informal chat over a drink. About 100 attendees showed up, of which 17 farmers correctly filled in the post survey. We eliminated answers of four other stakeholders who were not farmers from the analysis. Subsequently, we interviewed 9 out of 17 by telephone approximately six months after the OFD took place.

The researcher filming during the OFD wore an action camera under the chin with an additional audio recorder, to be as less intrusive as possible. The researcher asked permission to everyone attending the OFD to use the video for research, stating that the images would not be published. One other accompanying researcher was taking field notes wearing an additional audio recorder, mainly as back up for the first recorder. Due to a lack of means in terms of camera's and available researchers in combination with the explorative nature of this study, only the mentioned audio and video recordings were done.

Data analysis

We analysed the data of the video using Nvivo Pro 11. Each time slot representing another concept was separated and coded. Some time slots were to hard to seperate in concepts thus capture more then one. First the occurrences during the time slot were written out. Next, each time slot was categorised into one or more of the targetted concepts described in the video analysis guideline. The answers given during the telephone interviews were also structured and coded using Nvivo Pro 11. Data obtained through the post demonstration self-administered surveys were analysed in Excel 2016.

Reflection on the video analysis guideline: physical embodiedness and social embeddedness

Regarding our methodological approach, we noticed during the coding process that it was hard to make an objective distinction between categories. More precisely, between the two categories we defined for physical embodiedness: 1) engaging with different senses with the environment and 2) hands-on opportunities. We realised that hands-on opportunities for experimentation are usually combined with 'engaging with different senses with the environment'. We experienced the same overlap for social embeddedness, for which the categories interconnections and network building (1) and informal conversations between participants (2) appeared hard to distinguish. Here the first category could be defined as a part of the second one. This overlap could be solved by either defining the categories more specifically, or merge the categories into their umbrella concepts of physical embodiedness and social embeddedness.

Tabel 1: Video analysis on physical embodiedness and social embeddedness of one Belgian on-farm demonstration

Conceptual category	Physical embodiedness	Social embeddedness
Video target	10' engaging with different senses with the environment (smell, touch, hearing, taste, and sight) + 10' hands-on opportunities	10' interconnections and network building + 10' informal conversations between participants

Exemplary written out video sequences	1) The machine starts driving and working the soil. Attendees are walking right behind the working machine and look very closely at the soil, lokking at the effects of the machine on the maize and the weed, some attendees are touching the soil for examination. 2) The second machine starts driving. As with the first machine, attendees closely follow the machine and some touch the soil and discuss the soil together. 3) Walking to the next machine: attendees touch the soil and discuss together lively. 4) The third machine starts driving. Again attendees follow immediate after the machine and investigate the machine and the soil closely. A lot of them also touch the soil.	1) A few people are listening to the advisor. Most of the attendees stand further away, talking to each other and looking at the soil. 2) The second machine starts driving. As with the first machine, attendees closely follow the machine and some touch the soil and discuss the soil together. A lot of them stay a little behind to talk to one another. 3) Walking to the next machine: attendees touch the soil and discuss together lively during the walk. 4) While the advisor is explaining the third machine, about half of the participants are talking to each other.
Video sequences	32'29''-33'39''; 35'14'' - 36'31''; 37'42'' -38'46''; 43'16'' - 45'46''; 51'56'' - 54'45''; 58'58'' -1h03'19''	33'39'' - 34'28''; 35'14'' - 36'31''; 37'42'' -38'46''; 38'46'' - 43'16''; 55'19'' - 58'58''
Part of total time video: 1:03:19	about 13'	about 10' on video, but happend during the whole visit, except during the 22' introduction

We witnessed for this OFD physical embodiedness in terms of farmers watching the machines working in the field and taking the opportunity to immediately examine the soil worked by the machines through touching, feeling and even smelling the soil. While examining the video, these opportunities of sensory experiences seemed to fuel informal conversation between farmers. Consequently, there is an overlap in video sequences categorised as physical embodiedness and social embeddedness.

With about 13’ of observed moments of focus on physical embodiedness of 1h 3min total video time trying to grasp what the biggest part of attendees was doing, we believe this provided strong learning opportunities. However, there is room to elaborate on this type of physical experiences, both in amount of time and in variation. For example a more structural and formal introduction of this type of experiences could be applied, instead of counting strongly on the personal initiative of farmers to engage in these opportunities as was the case in this OFD.

Examining what we observed in relation to social embeddedness, we believe this OFD provided a strong context. After the 22’ min introduction during which most participants were silent, attendees felt free to stay behind and talk in the field during the rest of the duration of the OFD. However this meant for attendees a trade-of between listening to the advisor, who talked during almost the complete 1h 3min except for when the machines were working (less than 13 min), and talking to each other.

After the demonstrations in the field, many attendees stayed behind talking over an informal drink. This was not part of the video, but entailed an important opportunity enhancing social embeddedness, reinforced by about a 100 attendees.

In retrospect, more audio excerpts of informal talks between farmers could have been an additional valuable information source to grasp reflection processes.

Reflection on the video analysis guideline to enrich the peer learning framework (Cooreman et al., 2018)

Tabel 2: Video analysis on communication initiation and interactive knowledge creation of one Belgian on-farm demonstration

	Communication initiation		Interactive knowledge creation	
Original video target	5' Sharing own knowledge in formal group + 5' Formulating own values in formal group (participants)	5' Formulating questions in formal group	5' Open discussion in formal group + 5' Negotiatin g conflict in formal group	5' Knowledge scaffolding by the main demonstrator
Exemplary written out video sequences	Not observed	Question from the public: is this machine available through a contract worker? - Yes, here in the neighbourhood. Question 2: And renting? - No, not structurally, just colleagues sharing amongst each other. ; The demonstrator is adjusting his machine, while the advisor keeps talking about the machine. Another attendee asked about the benefit of a certain specificity of the machine, which the advisor shortly answers. The advisor answers a question of an attendee on the specific benefit of a type of machine in comparison with	Not observed	23' min of introduction on the theme of mechanical weed control.; +-3 times 5' of the advisor explaining the specifications of the machine while sometimes pointing at the specific parts of the machine.; The advisor explains the specificities of the third machine. A handful of attendees meanwhile touch the machine. The advisor explains a lot about the springs on the machine. Now more attendees touch the machine (about 20 during his explanation). Still, more than half of the participants are not really listening to the explanation of the advisor anymore, but stand a bit further in the field, investigating the soil and

		another machine. The advisor elaborates on this.		talking to each other; More explanation on the springs of the 4th machine. The advisor points to the part of the machine while explaining.
Video sequences		31’21’’- 32’29’’; 34’28’’-35’14’’; 47’37’’- 49’14’’		0-19’01’’; 22’14’’- 26’53’’; 26’53’’- 31’21’’; 38’46’’- 43’16’’; 45’46’’-46’44’’; 49’14’’-51’56’’; 54’45’’- 55’19’’
Part of total time video: 1:03:19		+- 3’30’’		+-36’ 30’’

Underlying the process of ‘interactive knowledge creation’ in the peer learning framework (Cooreman et al., 2018), we observed knowledge scaffolding by the main demonstrator during about half of the complete time of the OFD (+-36’ 30’’), but we did not observe any ‘discussion or negotiating conflict’ in a structured manner or in formal group.

With respect to ‘communication initiation’ by participants, we also did not observe any sharing of the own knowledge or formulating own values by farmers in the formal group. Probably this happened during their informal talks in smaller groups, but this did not happen in an organised way. We did observe about 3 min 30 sec of questions asked by farmers and answered by the adviser, which is only a small part of the total time of 1h 3min.

Reflection on OFD attendees learning outcomes as ideally fostered by a tactile space: reflection and adoption

Tabel 3: Post demonstration survey answers on questions related to reflection and adoption

	I thought about how I could implement some of the ideas and practices on my own farm.	I feel motivated to undertake some sort of action towards sustainable agriculture.	I am thinking about an action that I could undertake myself, because of the demonstration.
% Farmers (17) agreed or strongly agreed	94%	80%	54%

Considering the answers farmers gave on the post demonstration survey (Table 3), it seems that the OFD was succesful in stimulating reflection, and more specifically thinking about implementation. These numbers show that it is not because farmers don’t think about undertaking a specific action towards implementation (54%), that they didn’t reflect about the possibility (94%). They might just decide, after some reflective thinking, that implementation is not the best option for them.

Providing more in-depth information, we additionally investigated telephone interviews conducted 6 months after the OFD took place. More specifically, we are itnerested in answers to what they learned and what could have made the OFD more interesting for them, to grasp their reflection process. Secondly, to grasp their thinking on adoption, we investigate their answers on ‘Did the demonstration event result in you doing something new or differently (on your farm), or do you plan to change something?’ and the answers to the elaborating open questions ‘What exactly?’ or ‘Why not’.

Seven out of nine farmers stated they learned something because of the attended OFD. One farmer that didn’t learn something also couldn’t give an answer when asked what could have made the OFD more interesting for him. The other said: ‘I looked a lot at the camera-controlled machines, but if I specifically learned something? Not really.’

Of the seven farmers, three mentioned they learned about the new developments in the technical automation of the machines. Two of these three farmers added a reflective thought, for example:

Well it confirms for me that everything is gradually becoming more and more automated regarding control, GPS, follow up. I just think that here, we do not have enough space to put in practice what is possible. I just read in a magazine that in the UK, they have farms covering about 5000 hectares. More becomes possible then, compared to what is possible here.

Three other farmers mentioned learning specifically about the difference in application between machines regarding type of soil and type of crop, including the difference in price.

It was very informative to see that not everyone's situation is similar in terms of his or her soil. These machines will work better on one soil compared to another. It was nice to see that there was such a big interest and that it was very well organised. However, I wish there was a machine that could be applied to 'lighter’ types of soil.

One farmer mentioned networking and exchanging of opinions on problems with other farmers as his main focus of the day.

I went there out of interest. We were not looking to buy new machines. We mostly went to see what is new on the market and actually mostly to meet with colleagues to exchange opinions on problems of the moment of the year.

When asked ‘Can you think of a way that the event could have been (even) more interesting for you?’ four out of nine farmers could answer the question. Two of them wanted to see the application of the machines on fields with different crops.

This demo specifically focused on weeding in maize. It would have been nice to see the machines working on fields with different crops.

Another farmer thought the demonstrator could have been more informed but was happy with the attendance rate, probably for networking possibilities. The fourth farmer reflected on the value of contract workers and working together. Also, he mentions the advantage the machine can have regarding the structure and moisture balance of the soil, which refers to knowledge that can be gained and strengthend through touching the soil during the demo.

I have two types of new weeding machines, and if you know how many hours a year I actually use them, it is hard and actually not cost-effective. Contract workers could be a solution for that. I have these machines because I farm organic, but if I use these machines at conventional farms, you notice that they have an advantage regarding the structure and the moisture balance of the soil. I think we should aim more at working together.

Secondly, three out of nine farmers answered 'yes' when asked if the OFD resulted in doing something new or differently on their farm or in planning to change something.

Our farm has always been a conventional one, now we want to transform to organic, so now we are looking with our son to convert our machines to mechanical weeding ones.

Yes, I am more interested in the machines, but the new techniques are going very fast, with for example colour recognising and so on. I think the contract workers are not involved enough. They are normally the leaders when it comes to changing practices.

It stimulates me to work differently, maybe just changing the elements on the machines, instead of buying a new machine is already an idea.

When asked 'why not', two farmers stated they were too close to their retirement to invest in the machines and one just bought new machines. One farmer already had a lot of experience with the mechanical weeding machines and one is still making up his mind.

Not yet. Probably in a couple of years. I have ideas on what I want to do but I am not a 100 percent sure yet. These demo's inform me and add information when thinking about my ideas, but I did not make a decision yet.

Conclusion

We aimed to investigate on-farm demonstrations (OFDs) as tactile spaces and places for peer learning through video analysis as a part of a mixed methods approach. To do so, we developed a new video guideline for analysis as a set of targeted video shots related to learning activities (communication initiation and interactive knowledge creation) and to the concepts underlying a tactile space (physical embodiedness and social embeddedness).

Tabel 4: Summary of the results

Suggested ameliorations of the data gathering tools	OFD as a potential peer learning and tactile space
Video analysis guidelines: more specifically defining categories underlying a concept or merging the categories into their umbrella concepts more audio excerpts of informal talks between farmers more people recording video and audio	94% reflected about implementing 54% thought about undertaking an action Barriers: machines should be seen working on fields with different crops, prices of the demonstrated machines Farmers seemed to reflect and think actively about opportunities for their specific situation
Telephone interviews: Add specific question on learning methods related to video analysis guidelines	Future research needed: A lot of time and effort to knowledge scaffolding by the advisor, but no formally organised discussions or negotiating conflict Maybe knowledge shared by the demonstrator in combination with sharing and discussing in smaller informal groups is enough to trigger reflection?

	Small but present focus on physical embodiedness and an observed rich learning environment Similar OFDs could elaborate on physical experiences, both in amount of time, deliberate organisation and variation.

Reflecting in retrospect on this video analysis guideline applied to one Belgian OFD, we suggest enhancements for future use. This mainly to solve overlap in time slots belonging to more than one concept, either by more specifically defining categories underlying a concept (by for example distinguishing between formal and informal groups), or by merging the categories into their umbrella concepts of physical embodiedness and social embeddedness. In addition, more audio excerpts of informal talks between farmers could have been an additional valuable information source to grasp discussion content and reflection processes. Therefore, more people recording video and audio could be necessary, when it concerns a big group as in this exemplary case. Then, the concepts presented in this paper could be divided between people recording, providing a possible solution regarding the rather arbitrary goal, now specified in minutes.

We complemented this video analysis with post demonstration survey questions and longitudinal telephone interviews to grasp farmers' reflection and adoption processes. These results from the post demonstration survey show that it is not because farmers don't think about undertaking a specific action towards implementation (54%), that they didn't reflect about the possibility (94% did). In fact, it seemed almost all of our participating farmers thought about implementation of the ideas and practices on their own farm, which is a very important first step and goal of this OFD. Taking it a step further, apart from requests to see the machines working on fields with different crops than maize, prices of the demonstrated machines seemed to be the biggest barrier for adoption. However, farmers seemed to reflect and think actively about alternatives as for example found in contract workers, working together and share a machine, and changing parts of the machines without buying a whole new machine.

The video analysis resulted in a clear overall picture of how the OFD stimulated learning processes underlying concepts of a peer learning and tactile space. For example regarding interactive knowledge creation, a lot of time and effort went to knowledge scaffolding by the advisor, but no time went to formally organised discussions or negotiating conflict, although we know from literature this aids the reflection and learning process (Cooreman et al., 2018). With respect to 'communication initiation' by participants, we similarly did not observe any sharing of the own knowledge or formulating own values by farmers in the complete formal group. This could mean that the knowledge shared by the demonstrator in combination with sharing and discussing in smaller informal groups is enough to trigger reflection. The opportunities of sensory experiences seemed to fuel informal conversation between farmers. Future research could elaborate on this finding, as could related in-depth questions additionally included in the telephone interviews.

With a small but present focus on physical embodiedness and an observed rich learning environment and set-up of the OFD, we suggest (Franz et al., 2009; Cooreman et al., 2018) for similar OFDs to elaborate on physical experiences, both in amount of time, deliberate organisation and variation. Additionally, the observed OFD provided a strong learning environment for informal social embeddedness because of the large amount of participants and the seemingly flexible field walk during which informal talking groups arose, even when the adviser was explaining. However, it meant for attendees a trade-of between listening to the advisor and talking to each other.

Overall, our study shows that with some enhancements, this mixed methods approach seems promising to grasp an OFD as a tactile and peer learning space triggering reflection, a first step in deciding on adoption. Additionally this method assists in defining strengths and weaknesses of an OFD in terms of aplied learning activities. We conclude that more research is needed, but we suggest it is beneficial to organise OFDs more as tactile and peer learning spaces to foster sustainable agriculture, using its' potential as a rich learning environment more effectively.

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THE ROLE OF FACILITATOR IN FARMERS’ DISCUSSION GROUPS

Helen Zarokosta [a], Alex Koutsouris[a]

[a] Agricultural University of Athens.

Abstract: The necessity for sustainable recourses management and preservation of farms’ competitiveness is widely recognized as a challenge to be met on an ongoing basis. This gave rise to communication models emphasizing on the multi-actor character and the complexity of transforming knowledge into effective practice. In such environments, knowledge seekers and knowledge providers often find themselves in alternative roles, while complexity hinders the dissemination of knowledge. Overcoming these difficulties brings to the fore non-instructional learning activities and knowledge brokers, aiming at facilitating the linkage among the actors involved in the creation, sharing and use of knowledge.

This study employs an action research approach to explore the formation of farmers’ discussion groups in stables and participants’ interconnections and experiential peer-to-peer learning processes. The study carried out in Karditsa Prefecture, Grecce, the period from September 2015 to January 2018 and focuses on the role of the facilitator and the activities undertaken. Data were collected through individual open interviews with participating farmers and the discussions during the groups’ meetings. Data were analyzed on the grounded theory principles. The results indicate that the role of facilitator concerned: a. activities focused on farm programming and management (individual farm level), b. developing interactions and connections among the members of discussion groups (group level) and c. developing interactions and connections within the local AKIS (system level). Among the problems identified were unwillingness for collaboration, difficulty in following common rules and lack of knowledge and experience on the part of facilitator. The study concludes that the role of the facilitator was critical and multifaceted. Success depended on creating conditions conducive to learning and building trusted relationships among the actors involved. Prerequisites for success include participants’ communication capacity, facilitator’ methodological knowledge and readiness to apply it appropriately and the facilitator’s engagement in a reflective learning process that goes beyond academic knowledge.

A DEEP DIVE INTO FARMER DISCUSSION GROUPS THROUGH THE LENS OF SOCIAL LEARNING THEORY

Elizabeth Dooley

University of Exeter, Centre for Rural Policy Research

Within the UK agricultural learning landscape, there are different collaborative mechanisms through which farmers can engage and learn from and with their peers. Farmer discussion groups (FDGs) are a longstanding example; they have been found to offer myriad benefits to participants, including economic, social, informational, capacity-building, etc. Building on the lack of understanding as to how learning happens in these contexts from an adult cognitive learning theory perspective though, Bandura's social learning theory was used to assess seven FDGs in the South West of England. The objectives were to determine 1) Is social learning occurring within FDGs, and if so, how and why? 2) Are there differences between types of FDGs with regards to promotion of social learning? And 3) should FDG learning processes be tailored differently in order to promote learning outcomes? The conceptual framework was comprised of the theory's critical elements: behaviour modelling, role modelling and critical self-reflexivity. An ethnographic methodology was chosen to gain deep insights into the dynamics, innerworkings and histories of the groups and gather rich empirical findings through participant observation, semi-structured interviews and feedback sessions. The results from a year of attending FDG meetings demonstrated that the elements of behaviour modelling and role modelling are present in all FDGs to varying extents. However, the element of critical self-reflexivity fostered through a proactive commitment to (facilitated) critical discourse was an emergent property amongst FDGs. It was largely absent from those which engage participants in one-way information flow rather than structured two-way knowledge exchange with deep sharing and challenging of tacit assumptions between members. Thus, social learning as understood according to Bandura's theory is not occurring within all FDGs. Collaborative learning processes that aim to promote social learning, therefore, should build capacity and skills, structure engagement and particularly train facilitators to be equipped to foster the critical discourse necessary to promote critical self-reflexivity and metacognitive development amongst participants.

FACILITATING TRUST FOR COLLABORATION IN SMALLHOLDER VALUECHAINS: A CASE FOR DIGITALIZATION?

Christopher Agyekumhene, Jasper de Vries, Annemarie van Paassen,

[a] Wageningen University and Research.

Abstract: Organizing collaboration between value chain actors is seen as offering a means of addressing existing institutional failures in smallholder contexts. This is because the complex challenges faced often require a harnessing of the capacities of multiple actors through collaboration. Various value chain governance mechanisms (VCGMs) have been explored as approaches to enabling new institutions needed for such collaboration in smallholder value chains. These institutional changes have however often been unsustainable in informal contexts where trust is often the key condition for collaborative relationships. Understanding the functioning of such VCGMs from a trust perspective could therefore provide key insights on the process of facilitating sustainable institutional change for collaborative relations within smallholder value chain contexts. Thus we explore how trust influences institutional change, in the context of VCGMs, for collaborative interdependent relations in smallholder value chains. The study is conducted through a case study of an interdependent smallholder maize farming arrangement in Ghana, West Africa. Our study shows that different forms of trust are present and combine in various ways in relations between interdependent actors within a value chain network. Trust should therefore not be perceived as one dimensional but a spectrum with relational, calculative and institutional trust playing key roles in facilitating collaboration between network actors. It is therefore important to determine the form of trust which dominate at different points in the network so as to better understand the key conditions which need to be supported in order to sustain trust between actors collaborating at that point. In facilitating institutional change in the maize farming context in Ghana, we argue that VCGMs should aim to facilitate supportive conditions for calculative trust in particular in order to build sustainable collaboration in the highly uncertain context. Enabling calculative trust requires information on actor performance as well as quick evidence of failure or emerging problems in the short term. We argue that facilitating this form of trust would likely require and presents a key opportunity for adoption of new forms of digital communication in value chain collaboration in the rural smallholder context.

THEME 2 – THE INTERSECTION OF SCIENCE AND PRACTICE: FARMING SYSTEM PERSPECTIVES

Agricultural sciences have to operate at the interface between technological, economic, political, natural, social and different knowledge systems. At the farm scale, science also has to intersect with the complex decision making environment, which presents certain challenges, risk and responsibilities.

Agricultural science can provide benefits of systematic observation, measurement and experiments, rigorous replicable methods, large data sets and analysis, however, how to make the outputs relevant to different production and management/decision contexts is a persistent question. Criticisms of uncertainty, lack of transparency are particularly pertinent to science supporting climate change adaptation.

Given the increasing reliance placed on science advancements, the need to understand how science intersects with practice is becoming more pressing; whether with respect to sophisticated modelling and big data, the promotion of concepts such as smart farming, sustainable intensification and ecological modernisation, or supporting farmers' adaptation to climate variability and resource challenges.

ADAPTING VITICULTURE TO CLIMATE CHANGE: A PARTICIPATORY SCENARIO DESIGN WITHIN A MEDITERRANEAN CATCHMENT

Naulleau Audrey

INRA, France

Abstract

In a context of climate change, water management is considered a determinant factor for the agricultural sector, including viticulture. Grape is highly climate-sensitive, regarding both quantitative and qualitative production, making consequently climate change challenging. In France, vineyards are usually rainfed, although irrigation tends to develop, particularly in the Southern regions. However, many concerns remain: sharing the resources between uses and users, water shortage, salinization, etc. Various growing practices contribute to the grapevine adaptation to water shortage under rainfed situations: plant material, planting density, training system, soil management, etc. Adaptation strategies may combine these adaptation levers, through considering current and future water resource, cropping and farming systems.

This paper lays out a methodology aiming at exploring the following hypothesis: "the *combination of growing practices at the plot and farm level, and their spatial distribution in a catchment could give significant leeway to adapt a perennial crop such as grapevine to climate change"*. In a typical Mediterranean catchment (Rieutort, 45 km²), a group of stakeholders, involved in viticulture and water management, is mobilized to design and evaluate adaptation strategies, built as alternative spatial distributions of cropping and farming systems. A chain of models is used for producing indicators, measuring the impact of the different adaptation strategies under future climate. The originality of this multidisciplinary approach lies in the coupling of (1) a participatory approach (data collection, scenario design, integrated assessment), and (2) modeling tools allowing multi-scale quantitative assessment (plot, farm, and catchment). The methodological framework is illustrated by the results of the first step: the initial local diagnosis, and a shared conceptual scheme of the studied systems. The two next steps, scenario design and quantitative modeling, will be based on these preliminary results.

Introduction

Climate change is one of the major sources of concern in the Mediterranean, as the hotter and drier climatic conditions threaten agricultural production (IPCC et al., 2015). A good example is viticulture as the growth conditions of the grapevine are moving away from the optimum (Jones et al., 2005). The increasing occurrence of extremes, such as drought and heat waves (Giorgi, 2006), threatens the grapevines quantitative and qualitative production (Schultz, 2010). As a perennial plant, grapevine production requires producers to plan far ahead when taking vineyard management decisions (Lereboullet et al., 2013).

Water resource management will be increasingly determinantal for the viticulture sector (Santillán et al., 2019). Despite the recent development of irrigation systems, many limitations and concerns remain. From sharing the resources among uses and users, to water shortage and salinization, the hurdles are numerous. However, various growing practices contribute to the grapevine adaptation to water shortage under rainfed situations (Medrano *et al.*, 2015): plant genetics (Duchene, 2016), planting density (Van Leeuwen et al., 2019), soil management (Bagagiolo et al., 2018), canopy management (Palliotti et al., 2014), etc. Local adaptation strategies should combine those technical levers, considering current and future water resources, cropping and farming systems (Nicholas and Durham, 2012).

So far, the scientific community does not reach an agreement to propose adapted cropping system to climate change that consider local-context feasibility (Ollat and Touzard, 2014). Two challenging issues could explain this situation. First, building an adaptation strategy requires massive data collection about the local context (Ollat and Touzard, 2014), including the technical aspect and the adaptation capacity of individuals (Lereboullet et al., 2013). Second, design and selection of effective adaptation strategies requires quantification of the possible impacts of climate change and the damages avoided by adaptation (Diffenbaugh et al., 2011). In other words, *ex-ante* assessments of adaptation strategies require a quantification of multi-criteria indicators. Above all, multi-scale evaluations are necessary to identify detrimental or beneficial effects of a plot adaptation when applied at larger scale. For example, irrigation strategies at plot scale will impact the overall water availability in the catchment.

On the one hand, participatory sciences support activities of knowledge engineering, prototyping and assessment, that is adapted to a design process (Loyce and Wery, 2006). In viticulture, such an approach has been mostly implemented in designing and assessing cropping systems with low pesticide use (Lafond and Métral, 2015; Thiollet-Scholtus and Bockstaller, 2015). This approach is doubly helpful: by selecting and collecting locally relevant data from various sources of knowledge; and by fostering a shared assessment of complex and multi-scale systems. On the other hand, the development of process-based models allowed to better quantify the climate change impacts on grapevines (Moriondo et al., 2015), and to evaluate adaptation options (Fraga et al., 2018; Garcia de Cortazar Atauri, 2006). But, those process-based models hardly reproduce adaptation strategy impacts, as they do not consider the local-context feasibility, the supra-plot scale impact and the spatial combination of technical operations. To the authors' knowledge, there exists no study until now dealing with the adaptation to climate change, combining a participatory design and process-based modeling tools in order to evaluate adaptation strategy at different scales. Therefore, we proposed to lead a participatory modeling approach (as defined by Voinov *et al.* 2018) to build and assess relevant adaptation strategies.

This work, as part of the continuation of the LACCAVE project (Ollat and Touzard, 2014), aims at exploring the following hypothesis: "*the combination of adaptation at the plot and farm levels and their spatial distribution in a catchment could give significant leeway to adapt a perennial crop such as grapevine to climate change*". The proposed framework tries to overcome the two identified methodological challenges – local relevance and quantitative evaluation – by coupling (1) a participatory approach (data collection, scenario design, evaluation criteria), and (2) modeling tools allowing multi-scale quantitative assessment (plot, farm, and catchment). More precisely, we co-design and evaluate different adaptation scenarios. We define an adaptation scenario by the combination of a climate scenario and an adaptation strategy intended by the local stakeholders. We expect to identify trade-off between water resource uses and grapevine production under present and future climate, for the different studied scale.

In this paper, we first outline the methodological protocol, divided into three steps: the conceptualization, the scenario building and the quantitative modeling. We focus on the interactive process between stakeholders and researchers. We then present the results of the first step: stakeholders identification, initial diagnosis, and conceptual scheme of the studied system, collectively built with local stakeholders. Finally, we conclude by explaining broader implications of our results and we consider future prospects.

Material and methods

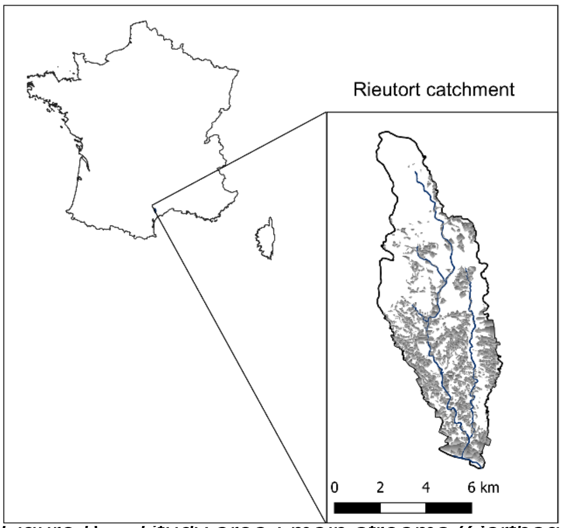


Figure 8 — Study area : main streams (Carthage BD) and vineyard plots (RPG 2017) in grey

The study area is the Rieutort catchment (45 km², 43° N, 3° E), a tributary of Orb River (Figure 8), located in the Languedoc vineyard. Grapevines represent 80% of the agricultural area of the catchment (1,500 ha). This catchment illustrates the regional wine-growing system diversity, notably with two Protected Designation of Origin areas (PDO) in the north, and a non-certified production area in the south.

Figure 9 shows the methodological general framework. The chronological structure is divided in three steps (Leenhardt et al., 2012; Voinov et al., 2018). First, the conceptualization phase aims at identifying, articulating and representing the relationships among the study system according to the stakeholder concerns (Voinov et al., 2018). The study system could be composed of crops (vine, cover crop or other productions), landscape elements (forest, rivers, reservoir, etc.), economic structure (cooperatives, PDO syndicates, etc.). Second, the scenario exercise tends to explore possible solutions to adapt to climate change. A scenario is defined as a combination of a climate scenario and an adaptation strategy, regarded as a spatial distribution of adapted cropping system in the catchment. The scenario exercise includes a representation of the initial situation, a description of changes and a description of an image of the future (Alcamo, 2009). Third, the quantitative modeling simulates the co-designed scenarios. The two last steps will be repeated allowing an increased confidence in the model and more creative and complete solution proposals (Voinov and Bousquet, 2010).

Methodological step		Step 1 Conceptualization			Step 2 Scenario Building		Step 3 Quantitative evaluation	
Intermediary production		Stakeholder identification	Initial diagnostic	Conceptual model	Climate scenario	Baseline + Adaptation strategies	Simulations	Evaluation
How ?	Who ?							
Individual interview	SH+R	X						
Climate modelling	R				X			
Workshop 1 (WS1)	SH+R	X	X		X			
Model library exploration	R			X				
Workshop 2 (WS2)	SH+R		X	X		X		
Model implementation	R					X	X	
Workshop 3 (WS3) and more	SH+R					X		X

Figure 9—Methodological general framework (R: researcher, SH: Stakeholders)

Stakeholders and researchers interact through a succession of workshops and model development (Voinov et al., 2018). Stakeholders are mobilized early in the process. The numerical model is determined after the conceptualization phase, reducing the gap between model and stakeholder representation of the system. The intermediary productions (initial diagnosis, conceptual model, climate scenarios, adaptation strategies) are presented or updated with stakeholders at least twice during the process. The repetition gives a better understanding and transparency of the process and the possibility to update the collected information and choices.

Step 1: Conceptualization Phase

First, we identified and selected the study participants through individual interviews. The first concern lay in involving a diverse group of stakeholders representing a variety of interests: farmers, institutional representatives of viticulture and of water management, vine collectors, extension services, etc. 21 semi-directives interviews were dedicated to: (1) identify the cropping and farming systems; (2) characterize the perception of climate change issue; and (3) identify the implemented or intended adaptations from different stakeholders. At least, the final work group gathered 24 persons, including four researchers that are considered as "neutral" and not stakeholders.

Then, the initial diagnosis has been constructed on the basis of the 21 interviews and the first workshop (WS1). Diagnosis aimed at identifying the different cropping and farming systems, as well as their local sets of constraints (Loyce and Wery, 2006). We divided the diagnosis into three parts: (1) description of the system (biophysical units, cropping and farming systems), (2) climate change perception (climatic events and impacts), (3) the adaptations to climate change (diversification, irrigation, variety, etc.) and their key variables and processes to consider building an effective adaptation strategy.

Finally, a conceptual model has been built in order to represent the system components and processes and their interactions. Indeed, the initial diagnosis being a static image of the current situation in the catchment, conceptual model will give the hierarchical and causal relations between elements that are required to assess the impact of a change in the system. Furthermore, the conceptual model is used as an "artefact", that is helpful for building and explaining the upcoming numerical model with the stakeholders (Barreteau et al., 2014). We relied on the initial diagnosis, completed by workshop discussion, to build the conceptual model: system inputs (climatic phenomena, adaptation and their sets of constraints), system processes, and expected outputs (impacted variables by climate change). Therefore, the researcher plays a role of translator transforming the narrative information of the first workshop into a conceptual model (Leenhardt *et al.,* 2012). The conceptual model is discussed and updated with the stakeholders in the second workshop (WS2).

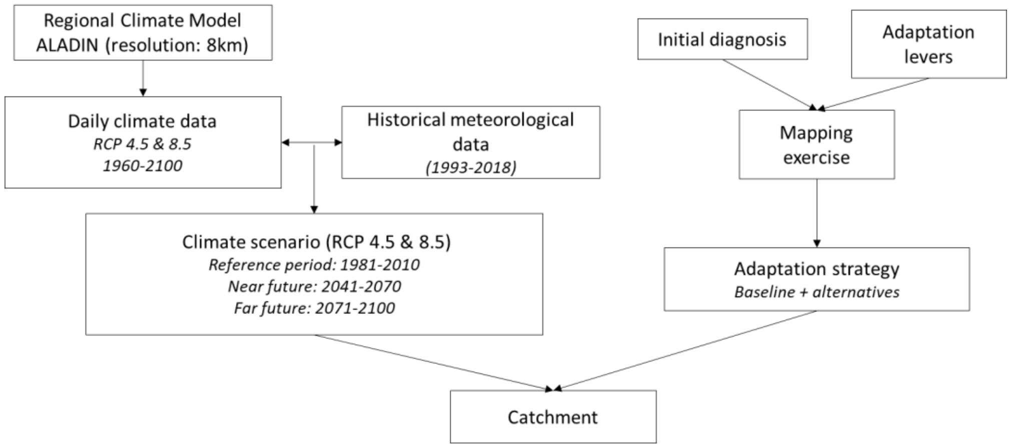
Step 2: Scenario Building

For the purpose of the study, we combine two types of explorative scenarios, as described by Alcamo (2009) (Figure 10):

Climate scenarios are provided by the Intergovernmental Panel on Climate Change (IPCC) and are considered as inquiry-driven scenarios,

Adaptation scenarios represent the spatial distribution of adaptation levers in the study catchment and are considered as strategy-driven scenario. Adaptation scenarios are also qualified as adaptation strategies as we do not *a priori* consider external factors of changes (e.g., regulation, market, etc.) (Börjeson et al., 2006).

Figure 10—General scenarios' framework



We considered two climate scenarios that represent a contrasted climate evolution for three 30-years-periods: one with a stabilization of the greenhouse gases emissions around 2050 (RCP 4.5) and another one without emission reduction (RCP 8.5) (IPCC et al., 2015). Climate data are provided by the Regional Climate Model ALADIN, developed by Meteo France. Daily-weather data are calibrated using 25-years meteorological data from Roujan station, located 16 km away from our study site (Molénat et al., 2018).

Adaptation strategies are alternative spatial distributions of cropping and farming systems, and landscape infrastructures. They are designed with stakeholders during WS2, through a mapping exercise. Although participation approaches engage more time, it ensures a better contextualization of the proposed solutions and the dissemination of the results (Van den Belt, 2004). The use of participatory approach when dealing with quantitative and modelled scenario requires a smart use of both qualitative and quantitative information (Leenhardt et al., 2012). In fact, adaptation strategies correspond to model inputs value, as a set of parameters. Knowing this, each input of the numerical model (e.g. soil type, slopes, practices management, commercialization, etc.) was translated in quantitative information through a participatory mapping exercise (WS2). Baseline scenario results from the mapping of current situation. Next, alternative future situation of the catchment are mapped through changes in cropping systems (e.g. irrigation, soil management, canopy management), farming systems (e.g. yield objectives, farm area) and landscape infrastructures (water reservoir, hedges). It is noteworthy that the pathway to reach the alternative image is not described in this exercise.

Step 3: Quantitative Modeling

Selecting the appropriate modeling tool is critical for any modeling exercise (Adam et al., 2012). The model selection should be driven by the participants' goals, the availability of data, the project deadlines and funding limitations (Voinov and Bousquet, 2010). We chose to use dynamic models because it keeps the causal effect of the climatic conditions on the variables of interest (Lane, 2008). For our purpose, the model is constructed by the researcher on the basis of the shared conceptual model. We select among current models only modules that can help in representing the current system and its evolution. The key model modules, selected by the modeler, are presented and discussed with stakeholders. The originality of our modeling approach is that we propose to couple different scales of the catchment, considering inter-relations between the biophysical processes at catchment scale (e.g. run-off), with the management strategies at field or farm scale (e.g. soil management). The coupling of models is executed on the OpenFluid simulation platform (https://www.openfluid-project.org).

Quantitative modeling allows the quantification of a given number of model outputs, that are discussed with the end-user (i.e. stakeholders) to generate model-based indicators (Bockstaller et al., 2008). Regarding stakeholder's selection, indicators concern mostly the productive system (yield, wine quality, diseases, etc.) and resource management (water use, water use efficiency, etc.). As far as we can tell, the assessment process will address more the changes in the system performances but not the performances *per se*, which could be too ambitious in such a complex and uncertain system.

The indicators of evaluation are not necessarily the raw model outputs (i.e., the indicators can be a simplified representation of the outputs (mean, median, distribution… through time and/or space)), but to some extent, they are closely limited by the model: how to quantify unmodelled processes and variables? We might not be able to model some key elements (e.g., biodiversity, carbon sequestration, effects of extreme temperature), because of missing data, unknown processes, or time calculation limitations. In that case, more qualitative assessment will be carried out thanks to data external from model calculation: input data, empirical knowledge, etc.

Preliminary results

Stakeholders identification

Table 8 — Involved stakeholders

Type of Stakeholders	Interview	WS1
Viticulture:		
Wine grower		
Cooperative	3	2
Particular cave	5	1
PDO syndicate	3	2
Cooperative cellar representative	1	1
Technical organization	5	—
Water:		
Agro-environmental animation	1	1
Regional policy maker	2	1
Local policy maker	1	—
Researchers	—	4
Total	*21*	*12*

Local stakeholders clearly expressed their concerns about climate change. Due to recent yield reduction and water shortage related to climatic incidents, they engaged solutions for maintaining their productive systems (irrigation projects, variety changes, hedges plantation).

Two types of local stakeholders were interviewed (Table 8): the vine growing system stakeholders (wine-growers, institutional representatives, cooperative cellar, and extension services) and the water management stakeholders (local facilitator, local and regional policy makers).

The participation to the first workshop was satisfying, despite the absence of some organizations. After the workshop, all stakeholders received the workshop detailed reporting and missing organizations' representatives were contacted for an update.

Initial diagnosis

The initial diagnosis was divided into three parts: (1) description of the system (biophysical units, cropping and farming systems), (2) climate change phenomena (drought, extreme temperatures, etc.) and impacted processes or variables (yield, wine quality, river flow, etc.), (3) a description of possible adaptations (diversification, irrigation, variety, etc.).

Three main types of cropping system are present in the catchment – describing the three main "terroirs" of the area:

vineyards located in the alluvial plain, characterized by high yields and availability of irrigation water;

vineyards located in slight hillside ("*côteau*"), characterized by a clay-limestone *terroir* and rain-fed;

sloping vineyards located in shale *terroir*, hardly mechanized and producing lower yields but higher-quality wine.

Concerning climate change, the main source of concern for stakeholders is the drought issue (Table 9). They reported frequent yield reductions, mostly due to the irregularity of rainfall during the year: extreme precipitation events and longer and unpredictable drought periods. They also noticed a general annual rainfall decrease. Second, the extreme temperature in summer is another source of concern. This climatic event, which had not been highlighted in interviews, was raised in the workshop. This directly referred to a climatic event that occurred few days before the workshop: an outstanding heat wave took place in southern France, with temperatures reaching more than 42°C in June 2019. In some parts of the vineyard, damage was clearly observed (leaf and fruit sunburn, desiccation). It is noteworthy that yield quality was not a major concern expressed during the workshop, despite the abundant literature about wine quality under climate change (Jones et al., 2005). In our study area, the solutions for limiting yield reduction seem to be more critical than increasing the yield quality, and thus it could be considered easier to maintain.

Table 9—Critical climatic events assigned to climate change and their impacts (X represent the occurrence of the climate change impact during interview or workshop)

Climate change perception	Climate change effects	Interviews	WS1
Annual rainfall decrease	Yield reduction	X	X
	Plant mortality	X	X
	Lower stream flow	X	X
	Economic impact	X	X
Rainfall intra-annual variability increase	Yield reduction	X	X
	Lower predictability of pest pressure	X	
Extreme rainfall	Flood		X
	Lower rainfall efficiency	X	X
Wind	Accentuation of dryness	X	
Higher temperature	Early harvest	X	
	Lower wine quality	X	
Extreme temperature in summer	Sunburn on fruit		X
	Leaf and plant desiccation		X
No cold in winter	Higher rate of mortality	X	

The third part of the diagnosis deals with adaptation options. A collective brainstorming session highlights the intended levers to adapt to climate change. The levers were arranged along the management plan of a vineyard (Figure 11). The stakeholders specified, for each of them, the biological or physical processes that could be targeted for adaptation and the climatic incident that can be tackled.

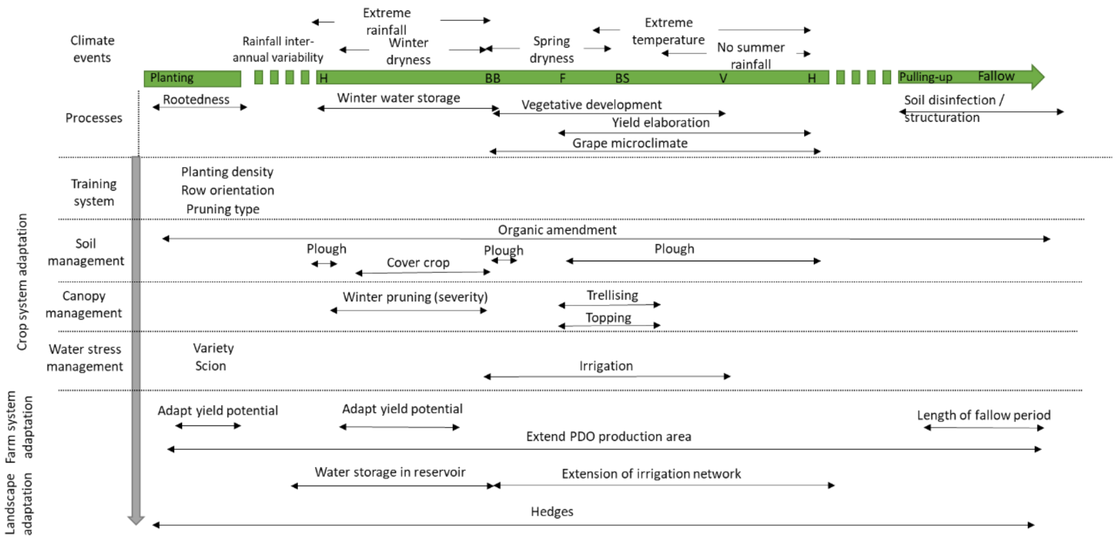


Figure 11—Adaptation options proposed by the stakeholders along grapevine cycle : BB = bud break, F = flowering, BS = berry set, V = veraison, H = harvest

The critical climatic events, illustrated in Table 9, were reported in the phenological cycle of vines. The processes (mentioned by the stakeholders) involved in the climate change adaptation were: the rooting of the vines during early years, the winter soil water storage typical of Mediterranean climate, the vegetative development and grape microclimate, the yield formation and the soil management during fallow periods (after vines have been pulled-up).

Figure 11 also confirms the implication of three scales for adaptation, from crop to landscape. These scales are closely interconnected. For instance, the extension of the irrigation network may influence the irrigation possibilities at the field scale. In addition, the extension of certified high quality wine area (PDO) may also influence the planting choices (imposed density, variety choice) and the productive period (yield limitation, irrigation rules, etc.).

As far as the adaptation timing was concerned, different levels of adaptation were highlighted. Stakeholders considered both planting choices and seasonal management as critical to plan a long-term adaptation strategy. On the one hand, fallow management (length, amendments and soil preparation), plant material and training system choices (row orientation, density, pruning system) have an impact on the global plant dryness tolerance. A good soil-plant adapted system ensures a long-term adaptation to climate change. On the other hand, seasonal management like soil management, canopy management and irrigation strategy allows an adaptation to specific climatic conditions of each year. It should be noted that most of the adaptation strategies have contrasting effects under different climatic conditions. For instance, topping should be more severe in wet years, preventing pest dissemination, but lighter in other hot years, preventing eventual damages caused by the sun. Stakeholders emphasize the necessity of a flexible adaptive capacity to specific climatic conditions of the year.

Conceptual Model

The design of the conceptual model was divided into three parts: model inputs, model components and associate processes, and model outputs. Model inputs are the climate variables, the management practices, which are those highlighted as adaptation levers and the context underlying adaptation feasibility. Model components are objects on which climate change, or its adaptation, have an impact. These components are in interaction (competition, services, management, etc.). Model outputs are the variables of interest impacted by climate change (yield, income, water use, etc.). The resulting conceptual model (Figure 12) represents the functioning of the catchment and the identified adaptation levers as described by stakeholders during the first workshop.

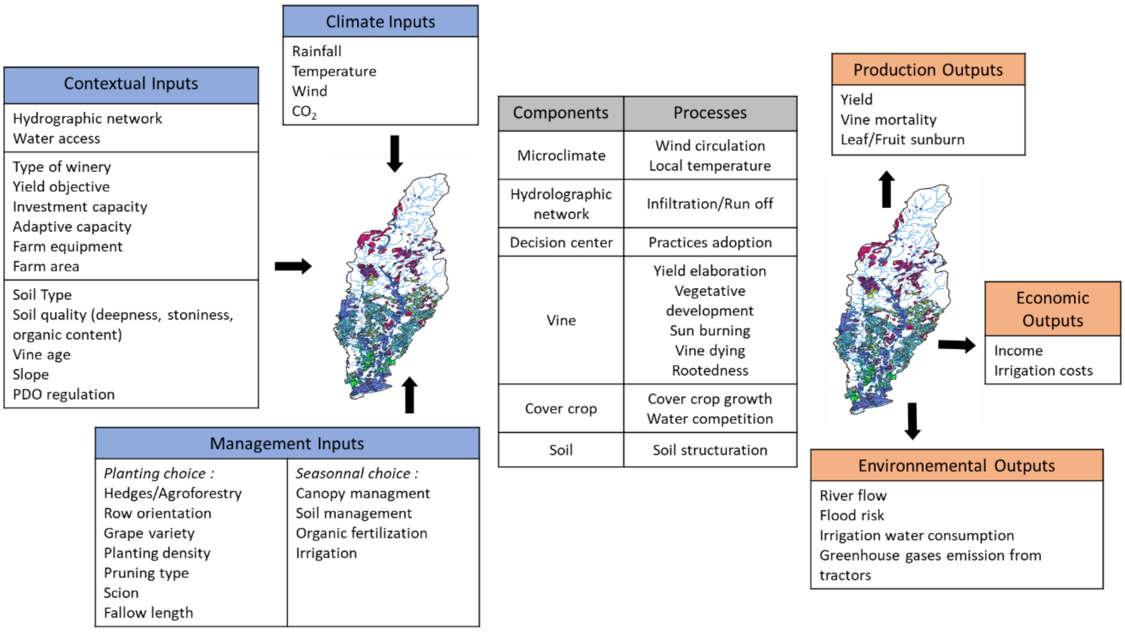


Figure 12—Conceptual model of a viticulture catchment under climate change. On the left, model inputs. In the middle, the model components with associated processes. On the right, model outputs.

The conceptual model brings out the nested and interrelated spatial scales. Each field unit depends on a specific set of parameters (climate, soil, practices, etc.), themselves depending on its specific location in the catchment and on the characteristics of the farm they belong to. Consequently, we can expect to represent a large range of situations in the catchment. Field scale remains the more detailed scale in which adaptation levers are numerous, but their feasibility can depend on the upper scales. Farm level is only described as the decision center, since wine-growing systems being monoculture systems, there is no other cropping system to consider. The choice of seasonal practices includes soil management (number and date of plough), organic fertilization, irrigation management and canopy management (topping, trellising). Adaptive capacity is defined by stakeholders as the level of knowledge and training of the wine-grower, which allows a well-adapted cropping system to plot specificity. Catchment level is characterized both by water circulation and availability, and by microclimate specificities.

Ideally, the numerical model should closely reproduce the catchment as described in Figure 5. However, we will not be able to model all the identified processes, neither than inform all the input variables. So, the decision will be taken by the modeler to be as close as possible to this first scheme, keeping in mind the predictive capacity of the final model. For example, high temperature effects on vine yield (sunburnt, desiccation) are poorly considered in current models. As a consequence, modeling results could alleviate climate change impacts, especially in the hottest years. The illustrated gap between conceptual model built from stakeholders' point of view (Figure 12) and conceptual scheme of the definitive model (to be constructed) will be explicitly presented and discussed during second workshop. Through stakeholder's empirical knowledge, completed by scientific literature, we could be able to integrate qualitative effects of unmodelled phenomena in our analysis.

Discussion

The proposed methodological framework is based on a first hypothesis: neither the modeler himself, nor stakeholders themselves, know how to assess numerically climate change impacts and the effects of adaptation strategies. In the present study, a model is constructed by coupling existing models to fit, at best, the stakeholders' representation of the system. Mobilizing the stakeholders early in the process improves the value of the resulting model in terms of its usefulness to decision makers, its educational potential for the public and its credibility within the community (Voinov and Bousquet, 2010). Therefore, the first difficulties arise from the confrontation of this representation, and the modeling capacities of existing models. In other words, even if stakeholders take part in the modeling process by expressing their expectations, the modeling exercise remains on the hand of the researcher. The influence of stakeholders on modeling choice can be questioned. Our participatory modeling still addresses three methodological advances. First, the participation of stakeholders is helpful in giving priorities to the processes to be considered. These processes can be already modelled or not, and with enough or too much detail. In a certain extent, stakeholders questioned the modeler on his own models and development perspectives; and in the other extent, the modeler shares scientific model-based knowledge with stakeholders. Second, participation is crucial to parameterize the model so as to fit to local conditions. The level of data details depends on the time and willing of stakeholders. Third, the validation of such a coupled model is a difficult task, because it mixes different epistemological references. Some modules of the model, which represent the natural and biophysical dynamics, may be validated with traditional methods in similar context areas. But the complete model cannot be validated in this way due to the absence of experimental design in the catchment and to the simplification of the input data. Stakeholders participate to the validation of the complete model through baseline simulation analysis (Bockstaller and Girardin, 2003).

Maintaining the level of participation is crucial, and efforts on clarity and transparency are necessary. Intermediary objects that support the interactions between researchers and stakeholders (conceptual model, scenario narratives, model simulations) need to be simple and consensual. It is not necessary to multiply the artefacts. For example, a conceptual model can be used both as front-end model conceptualization and as a back-end tool for communicating about the model outputs behavior (Lane, 2008). A clear and shared translation between narrative qualitative facts and quantitative model components facilitate the scenario interpretation assessment (Leenhardt *et al.*, 2012). The clarity of the general method (objectives, limitations) and the transparency of the model ensure production of plausible, consistent, creative and relevant scenarios (Alcamo, 2009).

Participative modeling is used here to undertake a spatialized simulation-based assessment in order to identify the trade-off between water consumption and vine productivity, but not the pathway to reach the alternative solutions. Scenario analysis is helpful in comparing the performance of various combinations of adaptation levers considering their socio-technical feasibilities in space. However, we cannot assume that it will be sufficient to support a decision making process. Indeed, further investigation should complete this scenario design by external factors, both climatic and socio-economical, promoting or limiting the situation described in the future. An integrated assessment of each strategy also suggests inclusion of a greater number of indicators and of people, including more producers, inhabitants, elected representatives, etc. For this reason, the analysis of the first simulated scenarios is a first step towards a more integrated assessment, which could be performed through the remobilization of this modeling platform.

The present study could have implications for both research and policy. Our first results already raised questions that could guide further research, e.g. on the processes reducing water demand, favoring water use efficiency, decreasing temperature locally that would be favored, according to stakeholders, by hedges, goblet pruning or grafting techniques. Future investigations would require experiments and modelling development to quantify those possible effects. Then, the results that will be produced all along our study could help to design local policies. For instance, we will quantify the impact of developing new water reservoirs on vine production and water consumption. Such quantification is necessary to assess *ex ante* part of the impacts of those expensive infrastructures. Policy makers may also be interested in other beneficial adaptations we would highlight, which they could encourage and support through subsidies. The originality of our study is to consider the regional vineyard diversity, which could help policy specifications according to the different production systems.

Conclusion

The paper presents a conceptual and operational method describing the main steps of a participatory design approach coupled with modeling tools exploring the adaptation of viticulture to climate change. This method contributes to the achievement of the project objectives into two ways: (i) it considered the local conditions and feasibility of each adaptation lever in diverse viticulture systems, and (ii) it takes into account different scales, from field to catchment, in order to identify in a quantitative way, wine-growing systems adapted to future climate. A local diagnosis and a shared conceptual scheme of the studied system were the first steps settled for the co-design and co-assessment processes, and will be used all along the work. Based on the shared conceptual model, a modular model will be developed. Then, adaptation strategies, built as alternative distribution of cropping system in space, will be simulated and assessed under present and future climate. We mobilize participatory and modeling methods to propose and assess relevant adaptation strategies to climate change, locally adapted to wine-growing systems of a typical Mediterranean catchment, for better informed decision making from farmers and local stakeholders.

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THE ROLE OF SCIENCE IN FACILITATING A SUSTAINABILITY TRANSITION OF THE SMALL RUMINANT FARMING SYSTEM ON THE GREEK ISLAND OF SAMOTHRAKI.

Dominik Noll, Marina Fischer-Kowalski

Institute of Social Ecology, University of Natural Resources and Life Sciences (BOKU), Austria

Abstract

Sedentary extensive small ruminant farming systems are highly important for the preservation of High Nature Value (HNV) farmland. Both the abandonment of grazing, and overgrazing, have led to environmental degradation in many Mediterranean regions. On the Greek island of Samothraki, decades of overgrazing by sheep and goats have caused severe degradation of local ecosystems. The present study highlights the role of socio-ecological research in facilitating a sustainability transition of the small ruminant farming system (SRFS) on the island. By utilizing a mixed methods approach based on the conceptual framework of social metabolism, we show how long-term transdisciplinary research can achieve valuable scientific results and at the same time initiate a practical outcome. Sociometabolic results indicate clearly a regime change of the SRFS after 2002, and during the time period of our research. Between 1929 and 2016 the livestock and land-use system of Samothraki transformed from a diverse system towards a simplified system, solely used for small ruminant production. Total livestock units increased from 2,200 in 1929 to 7,850 in 2002, declining to 5,100 thereafter. The metabolic analysis conducted for the years 1993-2016 shows that the feed demand of small ruminants exceeded local available grazing resources at least for a decade. Monetary data shows that local small ruminant farmers generate 50% of their revenue through subsidies and have an income of 5,000€ per year per farmer on average. We discuss the role of science in the transdisciplinary research approach that shifts from mainly analytical, with the aim of understanding current problems and challenges, towards participatory with the aim of creating a space for knowledge co-production and preparing for change.

Introduction

Livestock represents a key element in society nature interactions and is responsible for more than a third of global land use in a wide range of ecosystems and 15% of global human induced GHG emissions (Gerber et al. 2013; Erb et al. 2016). Since ancient times, livestock plays an important role for human societies for the provision of food, working power and manure (Krausmann 2004). Livestock also represents a capital and nutrient stock and serves therefore as an important risk reduction strategy for vulnerable communities (Herrero et al. 2009). Since the onset of global agricultural industrialization in the 1950s, livestock successively lost its multifunctional purpose. Through the use of machinery and fossil fuels, draft animals vanished almost entirely, and animal manure got replaced by petrochemical fertilizers. Positive factors of industrialized livestock production, like higher feed to food conversion efficiencies and increased production output for a lower price, should not detract from the negative environmental, social and animal welfare consequences caused by this transformation. Industrialization of agriculture is among the most important reasons for the decline of small-scale farming and the abandonment of rural regions. The way animals are kept in industrialized production systems does not conform to their needs and must be questioned from an ethical point of view. Through industrialization of livestock production, grain became not only for monogastric species but also for ruminants an important external feeding resource. Thus, more than one third of global cropland is currently used for feed production (Steinfeld et al. 2006). The conversion efficiency of feed to livestock products was low in traditional farming but compared to industrialized systems they were more sustainable because animals mainly lived from feed not edible for humans (Krausmann 2016). Still, extensive, grazing-based ruminant and mixed crop-livestock systems provide globally 69% of milk and 61% of meat and are responsible for land use on 80% of all agricultural land (Herrero et al. 2015).

The Mediterranean represents one of the regions where semi-nomadic ruminant herding, mainly sheep and goats for dairy production, has a long tradition since antiquity. The specific environmental conditions in these regions limited intensive and specialized farming, why ruminant herding, often in combination with various forestry practices, still prevails in many regions until today. These characteristic landscapes, dominated by heterogenous plant communities of forests, bushes, herbaceous undergrowth and grassland, have undergone a long co-evolutionary process which generated "resilient ecosystems with a high species diversity, productivity and utility to society" (Kizos et al. 2013). This form of agriculture has in general lower production outputs than intensified forms and is classified in Europe as high nature value (HNV) farmland as it contributes to landscape level biodiversity and plays an important role as a repository of genetic resources (Plieninger et al. 2015). 40% of Greece's land area consists of mountainous, semi-mountainous and agriculturally least favored areas (Hadjigeorgiou 2011). These areas mostly represent HNV farmland on which rough grazing biomass is transformed into high value products, mainly by sheep and goats. The average small ruminant farm in Greece is mixed and rather small with 70 sheep and 40 goats. These farms represent mainly sedentary extensive systems in which a relatively small area is cultivated, the age of farmers is high and technical advances are limited (Hadjigeorgiou 2014). The socio-economic importance and multiple challenges faced by the sheep and goat sector in Greece and other Mediterranean regions call for a comprehensive research approach, focusing on environmental, social and economic aspects in the same time (Psyllos et al. 2016).

Since the publication of "Livestock's Long Shadow" (Steinfeld et al. 2006), research on the environmental implications of livestock has far progressed. The increased knowledge of problems and potential solutions are but only implemented on a small scale, why future research should increasingly focus on the practical implementation of proposed changes (M. Herrero et al. 2015). With the present study we aim at filling this research gap by focusing on the role of science in fostering a sustainability transition of the small ruminant farming system on the Greek island of Samothraki. The ongoing long-term research project facilitates since 2008 continuous exchange between scientists and citizens from various fields (Fischer-Kowalski et al. 2011; 2020). The conceptual framework of this approach is based on a socio-metabolic understanding of society-nature-interactions (Haberl et al. 2004; 2019) and combines analytical and management aspects towards sustainability transitions (Fischer-Kowalski and Rotmans 2009). In section (2.1) we introduce the study site, in section (2.2) we describe the conceptual framework and methodological approach and in section (3) we report on the main results. The discussion in section (4) is divided into the socioecological implications of the past transformation of Samothraki's livestock farming system and its main socioeconomic drivers (4.1) and the role of science to achieve a sustainability transition of sheep and goat farming on Samothraki (4.2). The conclusions are provided in section (5).

Material and Methods

The island Samothraki

Samothraki stretches over 178 km2 and is one of the very few hotspots of preserved archaic wilderness among the Greek islands. Its remote location in the north-eastern Aegean Sea, the pebbly nature of most beaches and often unclear land ownership averted economic exploitation and mass tourism on the island. The 1,611m high mountain range Σάος gives Samothraki its geomorphological character and shapes the distinct microclimates. While the northern side presents itself in lush green with old forest cover and numerous streams of drinkable water, the southern and western sides are shaped by a rather typical dry-summer Mediterranean climate and vegetation. A large proportion of the island's terrestrial area is part of the Natura 2000 network and since 2012 the island has been a UNESCO MAB candidate (Fischer-Kowalski et al. 2011; Petridis 2013). The island community of Samothraki is officially registered as 2,840 people but is subject to high fluctuations because many people leave the island in winter months or visit the island as tourists, seasonal workers or second homeowners. Of the 1,000 economically active residents, 40% work as livestock herders and small-scale farmers. The secondary sector is relatively underrepresented at 12%, while the tertiary sector employs 40% and consists mainly of tourism services.

The development path of recent decades has led to a wide variety of environmental but also social problems the island community currently must face. One of the major threats to local ecosystems was triggered by the transformation of the local agricultural system. Decades of overgrazing by sheep and goats resulted in biodiversity reduction and wide-spread soil erosion (Biel and Tan 2014; Panagopoulos et al. 2019; Noll et al. 2020). Since the mid 20th century, farms and farmers are declining, while the small ruminant population increased to unprecedented levels (Fetzel et al. 2018). Increasing feed prices, dependence on subsidies, the lack of marketing opportunities and little cooperation among themselves, have caused local farmers to find themselves in an economic deadlock situation that now threatens the very existence of agriculture on the island.

The conceptual framework of the socio-ecological research project on Samothraki

The point of departure for research was personal experience. Samothraki fascinated as a place of overwhelming archaic, natural and cultural beauty. Features that also appeared threatened. What followed was a transdisciplinary process involving scientists and experts from various fields and local citizens. This process aimed at creating a vision and an identity for the island community that would frame the local conditions not as "backwardness", poverty and lack of modernity to be overcome, but as a worthy heritage and asset to be developed in a targeted way. One result of this process was the idea that Samothraki becomes part of the world network of UNESCO Biosphere Reserves[31], a process that is still ongoing. Across the years, the many strands of research were guided by a basic systems model as outlined in Fig. 1.

[31] Biosphere Reserves are areas that encompass valuable ecosystems and social communities that wish to combine the conservation of ecosystems with their sustainable use. They are nominated by national governments and remain under sovereign jurisdiction of the states where they are located but become internationally recognized by UNESCO. Biosphere reserves form a world network under the protection of UNESCO. Within this network, exchange of information, experience and personnel are facilitated. At present, there are about 700 biosphere reserves in over 120 countries (See: http://www.unesco.org/new/en/natural-sciences/environment/ecological-sciences/biosphere-reserves/).

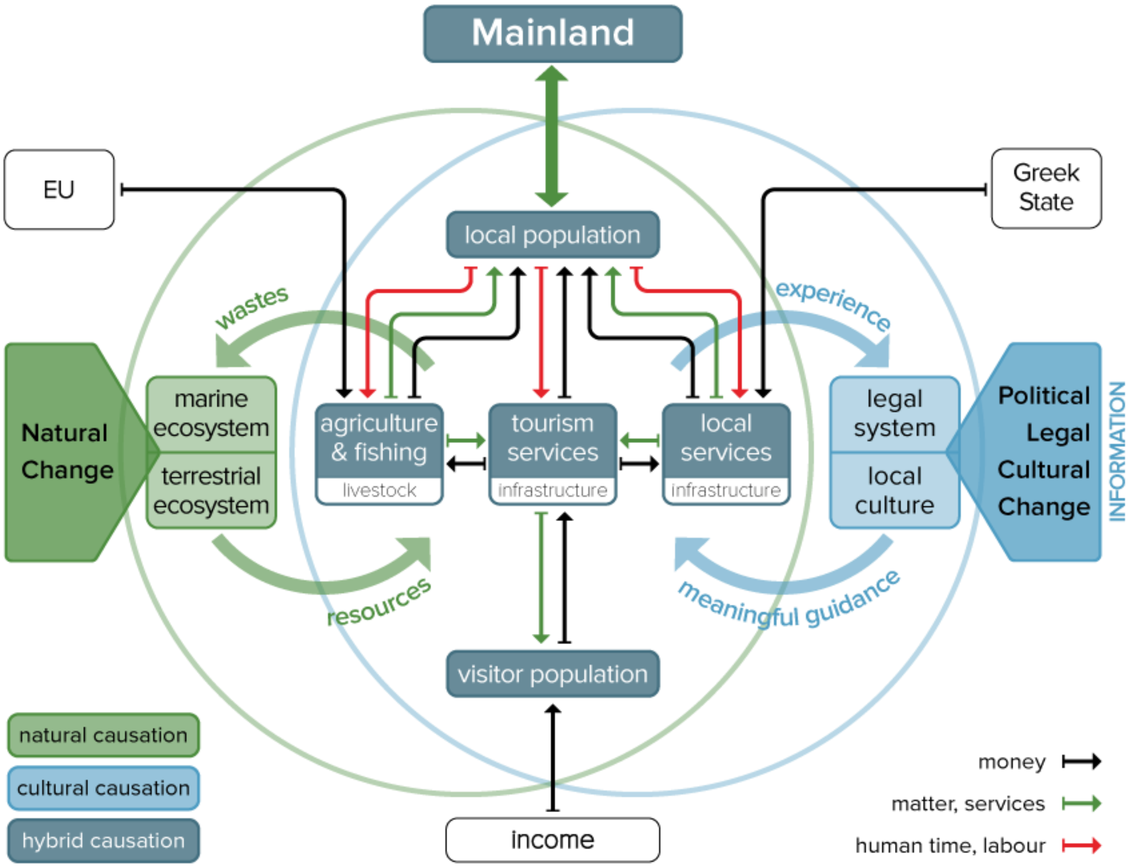

Figure 13: Sociometabolic system model for the relevant stocks and flows within and between the local society and its natural environment, required to identify critical social and/or environmental tipping points in the process of socio-ecological interaction.

According to this model, the sustainability of a socioecological system depends on whether flows required for maintaining societal stocks (humans, livestock, artefacts) can be organized. When critical stocks cannot be reproduced, the system might 'collapse' (Petridis and Fischer-Kowalski 2016). The reproduction of societal stocks requires flows of energy and material between societal systems and nature, referred to as social metabolism (Haberl et al. 2004; 2019). To strive towards sustainability, in this context, means to develop and maintain a social metabolism that serves the needs of the people without destroying the ecological balances of the natural environment, while being resilient to changing contexts. This implies to not increase socio-economic stocks excessively, to use natural resources carefully and efficiently, to create effective synergies between the sectors of the economy, and to develop a culture of social responsibility, collaboration and fairness (Petridis et al. 2017).

In the context of the current study we focus on the small ruminant farming system (SRFS) and its interconnections with its social and natural environment. The SRFS is defined as the small ruminant population (sheep and goats), its metabolic requirements, its material output in terms of products, the small ruminant farmers and their monetary economy. Terrestrial ecosystems provide the net primary production (NPP) consumed by small ruminants. The SRFS exchanges goods and money with the local population, including visitors and tourists. The political, legal and cultural framework is represented by rules and regulations of the Greek state, and the EU and local traditions. The EU provides agricultural subsidies through the Common Agricultural Policy (CAP) and the Greek state pays pensions to retired farmers. The local and visitor population receive money from external markets and through income from external sources (e.g. work or pensions). Wastes are not explicitly assessed in this study but are a relevant factor, especially regarding slaughtering residues and emissions.

The transdisciplinary research approach as applied in the present study

The transdisciplinary research approach is guided by a combination of analytical and management principles for sustainability transitions that aims at achieving both, academic output with a practical outcome (Fischer-Kowalski and Rotmans 2009). Applied to the small ruminant farming system (SRFS) this results in a dynamic research process (Figure 2) in which we improve our knowledge base of the local (livestock) farming system and increasingly engage farmers into a collaborative co-learning process. Blue arrows represent information flows between different stages of the research process.

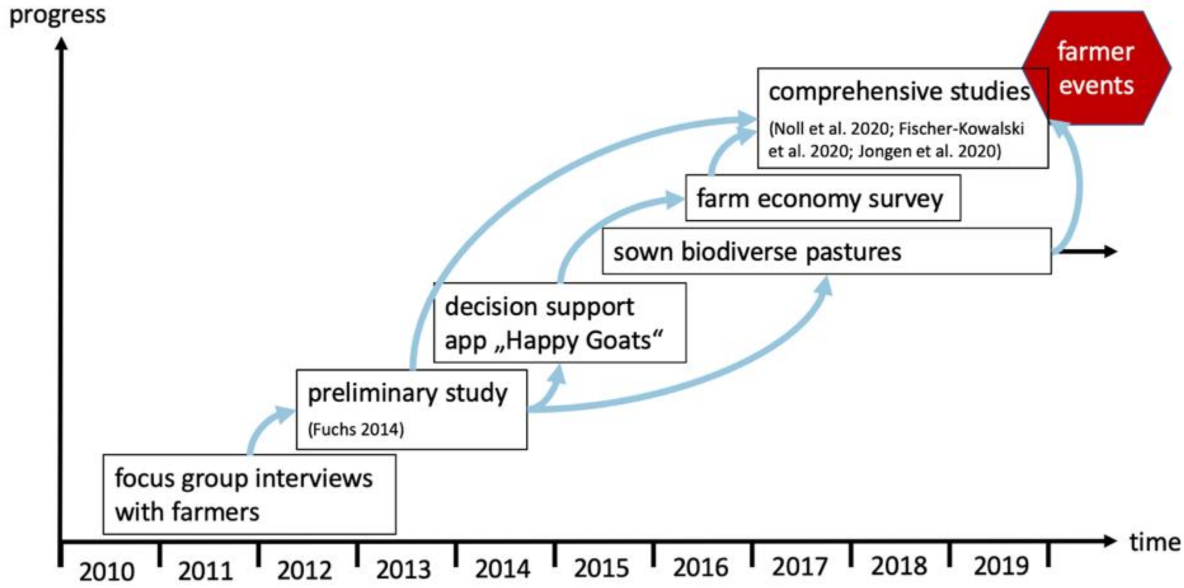

Figure 14: The transdisciplinary research process on the small ruminant farming system as applied in this project.

To enable the integration of data from various sources and thoroughly analyze the current socioecological crisis of small ruminant farming on the island, we utilize a mixed methods approach (Johnson et al. 2007; Kelle 2017). Focus group interviews with farmers and fishermen marked the beginning of research on the agricultural system of the island. Focus group interviews benefit from group interaction that can yield data which might otherways remain hidden (Ho 2006). Focus groups also allow for a discussion among participants and are therefore highly suitable for the co-creation of a transdisciplinary research process. In these meetings the researcher took over the role as moderator, initiating different topics of the discussion. We chose to use 1-2 moderators, including a translator. Students of the first Samothraki summer school helped to prepare questions and interpreting the outcome. During the interviews, some students were present and took notes. For a more detailed description and results of focus group interviews with various groups see Petridis et al. (2013). After these interviews in 2013, a preliminary study on the small ruminant farming system (SRFS) was conducted. Fuchs (2015) applied a combination of expert interviews and analysis of official statistical data to assess the environmental and socio-economic sustainability of small ruminant farming on Samothraki. This research led to the development of a decision support app which was then used to outline a survey to collect economic data from 23 local small ruminant farmers. This app is based on an agronomic model that combines metabolic data on the herd level with monetary data on the farm level. Simultaneously we initiated an experiment to apply a special seed mixture (sown biodiverse pastures - SBPs) that can store more carbon and is more resistant to grazing. We further conducted numerous expert interviews with farmers and other stakeholders between 2012 and 2018. An analysis of the transparency database for EU agricultural subsidies and public statistical data on demographics and agricultural production enabled the integration of official data. Annual summer schools enabled the involvement of numerous international students that helped to show our presence on the island and collect data. This approach has so far resulted in the completion of 4 scientific publications with a focus on livestock. Fetzel et al. (2018) uses land-use methods to estimate the grazing pressures on local ecosystems. Noll et al. (2020) utilizes a mixed methods approach, combining a metabolic livestock model with statistical and qualitative survey data to analyze the current socio-ecological crisis of small ruminant farming on the island. Fischer-Kowalski et al. (2020) provides a concise description of the socioecological transition of the island since antiquity and reports on the ongoing transdisciplinary research process. Jongen et al. (2022) uses vegetation and interview data to report on the social, economic and environmental implications of the ongoing experiments with sown biodiverse pastures. Students further completed 3 Master's Theses with a focus on the SRFS on the island. As an important next milestone, we drafted farmer events that would enable us to provide feedback from our research to farmers and local stakeholders and engage them further into the collaborative process. The COVID-19 pandemic had put this incentive at hold. A more detailed analysis of the outcome of this research approach is provided in section 4.2.

Results

Results are mainly focused on our sociometabolic and monetary assessments, as this data provides a good empirical foundation for the discussion of our transdisciplinary research approach. In section 3.1 we present the transformation of the local livestock farming system in changes of species composition from 1929 to 2016. In section 3.2 we plot the nutritional demand of small ruminants from 1993 to 2016 against the net primary production (NPP) of local ecosystems to assess environmental pressures associated with grazing. In section 3.3 we present the current economic situation of small ruminant farmers and show the low production output in comparison to the fairly high population numbers. For a more detailed description of these results and underlying methods refer to Noll et al. (2020). Results from qualitative interviews are integrated into the discussion sections and build the context for the sociometabolic results.

Development of total livestock units on Samothraki 1929 - 2016

Figure 3 shows the increasing significance of small ruminants in relation to other livestock species on the island from 1929 to 2016. Total livestock is expressed in livestock units [LSU], which express the nutritional requirements of each species. In 1929 the island had 490 [LSU] cows, 430 [LSU] pigs, 1,250 [LSU] Equidae (horses, mules and donkeys), 3,026 [LSU] poultry, 1,672 [LSU] sheep and 2,892 [LSU] goats. Small ruminants represented only 21% of all [LSU] in 1929, compared to cows (22%), pigs (10%), Equidae (45%) and poultry (2%). In 2016, small ruminants represent 93% of all LSU (2,276 [LSU] sheep; 2,428 [LSU] goats), while cows are reduced to 0%, pigs to 5% (277 [LSU]), Equidae to 1% (56 [LSU]) and poultry remained at 2% (77 [LSU]). Total [LSU] for small ruminants increased from 456 in 1929 to 4,478 in 1992 before reaching their peak at 6,735 in 2002, declining to values between 4,100 and 4,800 thereafter.

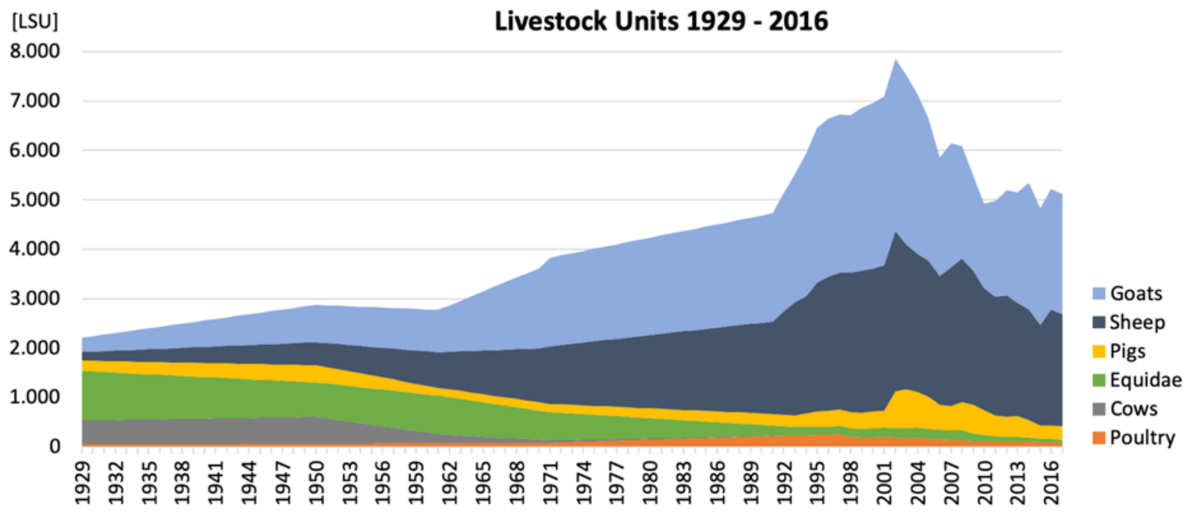

Figure 15: Development of total livestock units [LSU] on Samothraki from 1929 to 2016 (source: Noll et al. 2020).

Overutilization of grazing resources by the small ruminant population

Figure 4 plots grazing demand of the small ruminant population against the available NPP for grazing. In 1993 the grazing demand of the small ruminant population was 9,900 tC/yr, increasing to 13,700 tC/yr in 2001 and declining to values between 7,000 and 8,000 tC/yr thereafter. Herein we use two boundaries of the net primary production of biomass available for grazing (NPP) to assess the potential overgrazing and therefore degradation of local ecosystems. These two boundaries are based on the range of ±27% with regard to an uncertainty assessment for MODIS and NDVI data sources, derived from Jia et al. (2016). We find that the upper grazing boundary was exceeded for at least 10 years between 1995 and 2005, while the lower boundary was exceeded for almost the entire period.

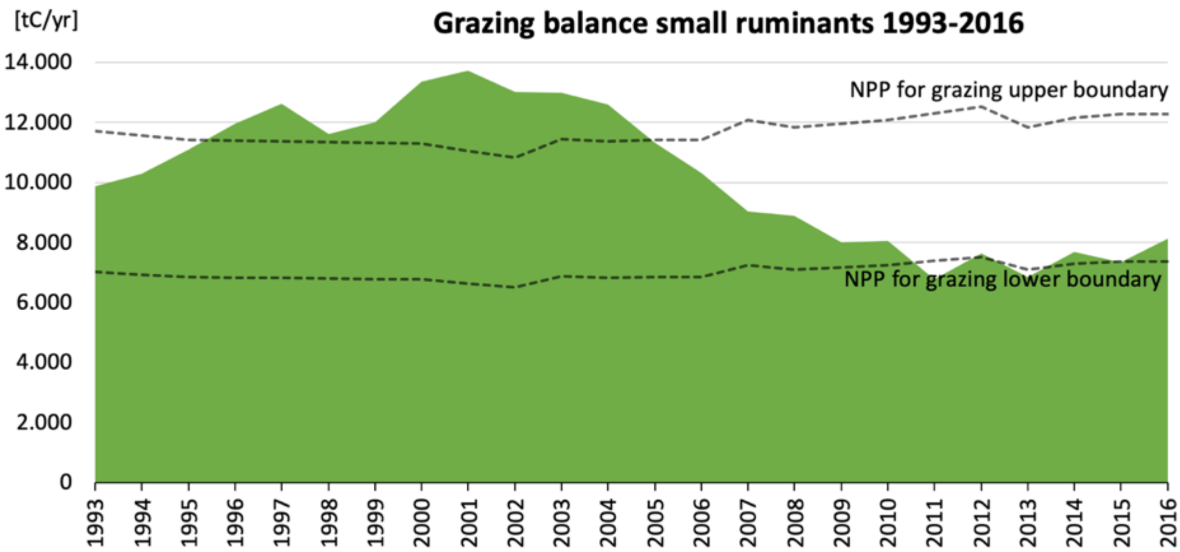

Figure 16: Grazing balance for the small ruminant population in tons of carbon from 1993 to 2016 (source: Noll et al. 2020).

The financial situation of small ruminant farmers in the light of underutilized production potentials

Figure 5 plots revenue against expenses to estimate the annual income for the average small ruminant farmer on Samothraki in 2016. One farmer generates a revenue of 25,000 €/yr through milk and milk products, meat and subsidies, which represent almost 50% of the revenue. Expenses for farm utility, processing, transport, land and animal maintenance were 20,000 €/yr, resulting in a net annual income of approximately 5,000 €/yr.

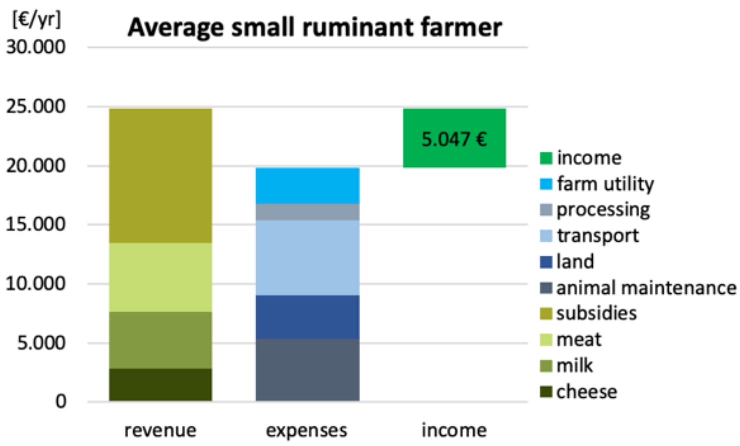

Figure 17: Revenue, expenses and income of the average small ruminant farmer in 2016 (source: Noll et al. 2020).

Figure 6 indicates the relatively low production output per animal if compared to potential production numbers. Actual production numbers for milk (blue solid line in secondary axis) and meat (red solid line in primary axis) are far below the potential production numbers (dashed lines and standard deviation bars of same color and axes) for the entire period. While potential production of meat and milk increases with the livestock population increase between 1993 and 2002, actual production of milk declines and meat stays constant. The increase of the actual milk production after 2003 can most likely be attributed to the reopening of the local dairy. This means that the increase of animals did not result in higher production output or higher income from products, hence leaving the farmers expectation of rising subsidies with rising animal numbers as the only plausible explanation.

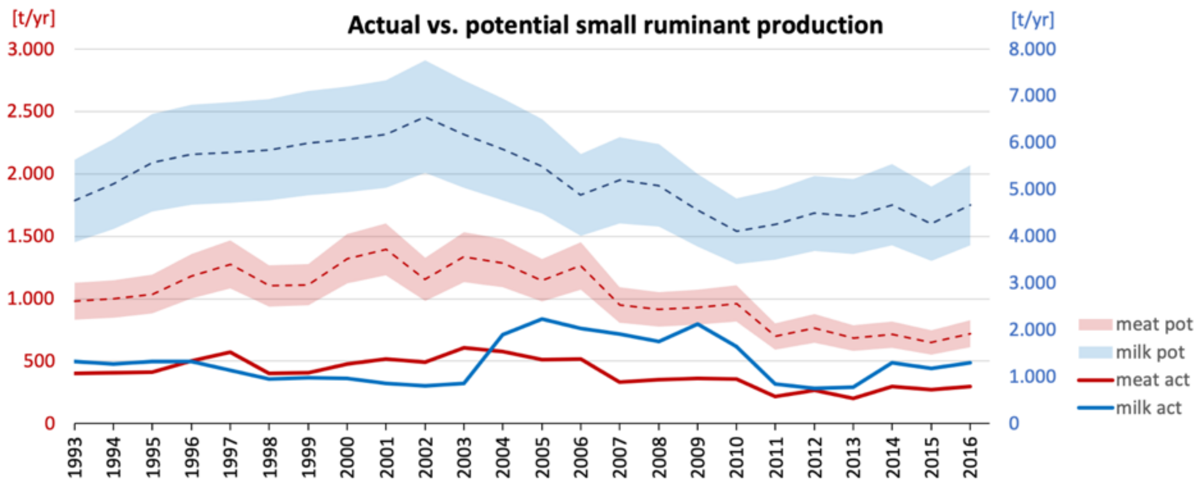

Figure 18: Actual vs. potential production of milk and meat from 1993 to 2016 (source: Noll et al. 2020).

Discussion

The integration of biophysical, monetary and qualitative data, in combination with results from previous studies analyzing changes in local ecosystems, enables us to comprehensively describe the current sustainability crisis of the small ruminant farming system (SRFS) and its socio-economic drivers in section 4.1. In section 4.2 we reflect on the applied transdisciplinary research approach in order to achieve a sustainability transition of the agricultural system on the island.

Socioecological implications of the past transformation of Samothraki's livestock farming system and its main socioeconomic drivers

Samothraki is a perfect example for the vicious effects of global industrialization on remote agriculturally shaped regions. The construction of the new port in the 1960s represents a key event for the development for the island, as it enabled transport of people and goods in larger quantities (Noll et al. 2019). The transformation of the local livestock farming system becomes evident in the changing composition of livestock species shown in Fig. 3. While there are only moderate changes before 1960, it is the time after that led to a complete transformation of stocking rates and species composition. In 1929 the livestock system had only 2,000 livestock units [LSU], was relatively diverse and dominated by Equidae (horses, mules and donkeys). The growth to almost 8,000 [LSU] in 2002 occurred almost exclusively in the small ruminant population. While the number of animals has been reduced since then to approximately 5,000 [LSU], the livestock system today is still dominated by sheep and goats. Expert interviews confirm the shift in the local livestock system. Up until the 1960s sheep and goat herders had a special position on the island. People who produced meat and had meat in abundance were considered rich by the community. Back then nobody possessed more than 100 animals and everything from the animals like meat, milk, wool and skins, was processed and used. Herds of goats grazed in the mountains in the summer and were chased down to the lowlands in winter and for slaughtering. In the past, animal numbers were kept below the carrying capacity of the island's ecosystems, as there were no feed imports. Despite the lack of statistical data on land use before 1993, the results of the present study clearly indicate that the land use system of Samothraki must have experienced a similar shift as described by Kizos et al. for the island of Lesvos. In their case study the authors show how since the 1960s "complex and multifunctional agrosilvopastoral land use systems were simplified to a pure livestock raising system" (Kizos et al. 2013). As evident from statistical data and confirmed by expert interviews, Samothraki's crop production is almost exclusively used for livestock feed today, while this was not the case prior to 1960. Initially farmers benefitted from good prices for their products, lush pastures and subsidies. Since recently the islands' ecosystems but suffer from overgrazing and erosion and farmers are caught in an economic deadlock.

Biel and Tan (2014) reported in their extensive survey about the flora of Samothraki that intense grazing and repeated "slash-and-burn" practices for obtaining pastureland, contributed to fundamental ecosystem changes and threats. A study conducted on the mountainous oak forests in 2017 assessed a sample of 940 trees and found no tree with a younger cambial age than 47 years. The authors concluded that 86% of the island's forests are currently threatened by overgrazing and have high regeneration priority (Heiling 2018). An analysis of the Normalized Difference Vegetation Index (NDVI) based on satellite images from 1984 to 2015 revealed a 40% reduction of large parts of Samothraki's landcover up until 2002 and only a partial recovery in the decade after (Löw 2017). A development that perfectly matches the increase of the small ruminant population prior to 2002. Grazing demand surpassed the upper boundary of the estimated NPP between 1995 and 2005 and the lower boundary from the 1980s until today (Figure 4). Thus, the small ruminant population seems to have overutilized grazing resources for at least a decade, or otherwise animals were severely undernourished. In reality, it was most likely a combination of both. The social and economic crisis of the system is reflected in multiple aspects. Of the 23 farmers interviewed for the farm economy survey, 22 have said that they see no future in farming on Samothraki and they advise their children to leave the island. The main reasons given were the increase in prices for feed, high taxes, reduction of subsidies and the declining market prices for products. For farmers in the north-east of the island the only local dairy is too far away, so they produce only small quantities of dairy products for their own consumption or in some cases their restaurants. Milking is largely done by hand and as prices are so low, it is not profitable for most farmers. The dairy can only process milk between April and July/August and 80% of their production is exported. According to the owner, in recent years they have needed to shut down the production in the middle of July as they cannot sustain their business over the summer. In Mediterranean regions many dairies stop taking milk during summer, as during the later stage of lactation, the coagulating properties of milk deteriorate, which has negative effects on yogurt and cheese production (Caroprese 2015). Many of the farmers interviewed claimed that the low capacity of the dairy is the main reason why they cannot generate any income from milk. Animals are often exported alive as they are purchased by external traders who take care of the transport and the slaughtering. If slaughtered locally, it can legally only be done in the slaughtering house. For many farmers, use of the slaughtering house is inconvenient and too expensive, so they slaughter by themselves and distribute the meat informally or may sell it in their own restaurants. The selling price per kilo is usually lower if the animals are sold alive for export. In the last 5 years, meat prices on Samothraki have dropped by 40% as traders agree on a price among themselves before negotiating with individual farmers. Traders benefit from the lack of farming cooperatives on the island that would allow a joint price policy on the part of the farmers. The partially coupled subsidy payments, or as stated by local experts, at least the perception that there is a strong correlation, continuously prevent farmers from minimizing their herds (Noll et al. 2020). The island is disadvantaged in free market competition as transport costs are high, processing facilities are lacking, and the market is flooded with cheap products, mainly from New Zealand and Australia. These difficulties are reflected in the current financial situation of local small ruminant farmers (Figure 5). Almost half of their revenue is generated through subsidies and main expenses are for transport and animal feed. This leaves the average small ruminant farmer with an income of about 5.000€ per year, too little to sustain their business and family. As stated by most farmers and local experts interviewed, without additional income it is not possible to live from small ruminant production on Samothraki today

The role of science to achieve a sustainability transition of sheep and goat farming on Samothraki

How could a successful sustainability transition of the small ruminant farming system on Samothraki look like and what did many years of research achieve so far? Samothraki needs to escape from the deadlock of the dysfunctional traditional farming system that can hardly secure an income for the farmers but destroys the vegetation cover and the landscape of the island. Exactly this landscape provides the core recreational and economic attractions for tourism. Ways of mutual support must be established between the island's core economic sectors, instead of mutual neglect, destruction and contempt. There are some ongoing processes that point to this direction: farmers are getting older and their overall numbers are diminishing; younger farmers see their chances in collaboration and finding new ways. Still, market conditions for agricultural produce are lacking, several legal regulations stand in the way of direct economic transactions between farmers and the tourism industry, and traditional political clientelism stabilizes large livestock numbers. With insight spreading, new European CAP regulations ahead, and the urgency of effective nature conservation becoming ever more apparent to everyone and being publicly declared by an application to UNESCO, chances are that the deadlock can be overcome.

Our transdisciplinary research approach aims at observing and describing the transformation processes of the livestock system on Samothraki, while “simultaneously increase societal capacity to reflect on them” (Schneidewind et al. 2016). This approach can be conceptualized as transformative as “by careful systemic analysis, it explores, together with the people involved, the realistic option space as well as the constraints of more sustainable alternatives” (Petridis et al. 2017). The research process therefore shifts from a mainly analytical starting point towards a participatory process with the aim of creating a space for knowledge co-production (Figure 2). At the beginning of the process it was important to gain an understanding of past and current conditions for small ruminant farming on the island. The sociometabolic approach proved to be the ideal conceptual framework for this goal as it enables us to generate consistent and comprehensive biophysical accounts for livestock systems, which can then be linked to other socio-economic processes (Erb et al. 2016). It goes much further than the often-applied focus on food to product conversion efficiencies, which has often been criticized as too narrow (Weis 2013). Most importantly, it provides an empirical basis for the definition of policy and management recommendations in order to overcome sustainability problems (Dumont et al. 2013). Through its strong focus on the assessment of biophysical processes within and between systems, it provides a complementary tool to various soft systems approaches in farming systems research (Darnhofer et al. 2012). The focus group interviews with local farmers and fishermen we conducted in 2012 (Petridis et al. 2013) set many of the guiding paradigms for our future research. We could identify major obstacles such as the degradation of pastures and high cost of supplementary feed, the crucial role of agricultural subsidies, the lack of information of marketing and production and the lack of cooperation between farmers. What followed after the focus group interviews in 2012, was a comprehensible study on small ruminant farming on Samothraki (Fuchs 2015). The author of this study highlighted for the first time the role of EU Common Agricultural Policy (CAP) subsidies for the increasing population of small ruminants on the island since the 1980s. It further provided an insight into the monetary economy of small ruminant farmers on the farm level and identified ways forward. This study led to the collaboration between the Greek IT-firm *Integrated ITDC*, the *Aristotle University of Thessaloniki*, and the *Leibnitz Centre for Agricultural Landscape Research (ZALF)* in order to develop the decision support app *Happy Goats* (happygoats.eu), which aimed at providing digital planning support for sheep and goat farmers in Greece and the EU. The initial goal was to use the app as a tool to encourage farmers to engage with their farm economy, especially in regard to small ruminant numbers and available pastures. The leading question during the development phase was: under current circumstances, how many animals would be an optimum for farmers’ income while in the same time preserving their pastures? Farmers were supposed to use the app in collaboration with other farmers. During the development phase it turned out that the app required much more input parameters than initially planned for. Therefore, it became too complex to be used by farmers themselves but required an expert for data entry and processing. The app was then used during the farm economy survey conducted with 23 small ruminant farmers on Samothraki from 2016 to 2018 and proved to be a suitable tool for approaching farmers on Samothraki. In 2015 we initiated a collaboration with the University of Lisbon spin-off *Terraprima* (terraprima.pt) in order to provide a special seed mixture to interested farmers. The sown biodiverse pastures (SBP) system is based on sowing up to 20 species/varieties of legumes and grasses that are self-maintained for at least 10 years, with all species used native to the island. The legumes, being ‘natural factories’ of nitrogen, minimize the need for synthetic fertilizers. SBP result in on average 30% higher biomass production and higher grazing resistance, is currently applied on 13 plots on Samothraki and is still ongoing. This experiment has proven to be highly useful to approach farmers and interest them for our research. At this point it is important to mention the role of local facilitators who build a bridge between scientists and local farmers. These facilitators must speak both languages and are vital for the whole project.

Since the beginning of the project we conducted numerous additional qualitative interviews with farmers and local stakeholders. Recent studies on the agricultural system of the island summarize and analyse this process (Fetzel et al. 2018; Noll et al. 2020; Fischer-Kowalski et al. 2020; Jongen et al. 2022). Recently a farmers' cooperative was founded on the island and the olive oil cooperative resumed its work. These cooperatives are crucial for farmers to achieve a better bargaining position with traders, and for the exchange with researchers such as in the farmer events envisaged. Our knowledge of the small ruminant farming system of the island has far progressed and represents a solid empirical foundation for assisting farmers in finding a shared vision and initiating change in a sustainable direction. Important was also the recognition that there is a big difference between older and younger farmers regarding the future of farming on the island. Younger farmers were much more willing to invest into this transdisciplinary process, as they were desperately looking for ways to improve the situation. From this group came the suggestion of additional frequent meetings that would enable continuous communication between farmers, researchers, and other stakeholders. Set as goal in our research agenda, we refer to these frequent meetings as *farmer events* in Figure 2 and were organizing the kick-off meeting for spring 2020. Then the COVID-19 pandemic put the whole process at hold, and we are currently working on its continuation. This co-created space should enable social learning processes for which it is central to combine "co-construction methods that explicitly address normative agendas and orientations, and appropriate governance amongst social actors and scientists" (Herrero et al. 2019). This means that these events should be open for farmers, scientists, politicians and other stakeholders to enable a collaborative climate in which we can define our common agenda.

Conclusions

This study shows vividly that effects of industrialization and national as well as EU agricultural policies on remote regions require special attention. The socio-ecological transformation of recent decades pushed the island community into a deadlock between economic development and preservation needs. Agriculture plays a key role in this process, as the increase of the small ruminant population triggered environmental and social problems which pose threats to the entire island community. The reasons for this development are manifold but are strongly associated with structural land use changes, global industrialization of agriculture and the agricultural market and finally the regional implementation of the EU Common Agricultural Policy (CAP). To enable a recovery of the local ecosystems, animal numbers must decline substantially. Local socio-economic contexts must be much better taken into account for a new CAP legislation after 2020. Direct payments should reach those who implement measures for sustainable small ruminant production. The flexibility on a national or regional level should be adapted in a way that a situation such as that reported in the present study can be prevented.

Herrero et al. (2015) point out that many ideas look great on paper but are only implemented by 10-20% of farmers, for a wide range of reasons. The authors further state that the understanding of environmental implications of livestock systems and factors that need to change has progressed substantially, while little is known of how to practically implement these changes. Transdisciplinary science can play a crucial role in facilitating this process on a local level, by engaging farmers in the scientific process and foster collaboration among and between farmers and experts from various fields. Our activities seem to have kicked off some real-world changes already, such as encouragement to form cooperatives, a reduction of livestock numbers by 40% and positive experiences with a new type of sown biodiverse pastures. Nevertheless, such changes require more patience and insistence from the part of researchers than they can easily afford

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INVOLVING STAKEHOLDERS IN THE DEFINITION OF PATHWAYS FOR MORE SUSTAINABLE BEEF FARMING SYSTEMS

Melchior Annick[a], Legein Louise[a], Mertens Alexandre[a], Stilmant Didier[a], Balouzat Jimmy[b], Mosnier Claire[b], Dimon Philippe[c], Echevarria Laurence[c], Madrange Pauline[c], Pineau Christèle[c], Pirlo Giacomo[d], Iacurto Miriam[d], Carè Sara[d], Hennart Sylvain[a]

[a] Walloon Agricultural Research Center (BE)
[b] INRA Auvergne-Rhônes-Alpes Center (FR)
[c] French Livestock Institute (FR)
[d] Council for Agriculture Research and Economics (IT)

Introduction

Agriculture faces many challenges, in particular ensuring food security for a growing human population, while facing resources depletion – resources that are also limited at the outset – in a context of uncertainty related to climate change. In addition, agriculture is objected to many criticisms, especially coming from media and society. Among the criticisms addressed to livestock farming in particular, the low conversion efficiency of livestock and the feed-food competition that livestock farming induces play an important role. However, recent works shed new light on this debate (Wilkinson 2011; Ertl et al. 2015; Mottet et al. 2017; Laisse et al. 2019), especially in the case of ruminant farming. Indeed, ruminants have the advantage of a diet essentially based on resources that are not edible by humans (e.g. grass). However, the evolution of the beef production towards systems relying on the use of concentrate feeds, much of which also have potential as human food, undermines this advantage.

The paper at hand presents the results of a still ongoing project that focuses on the decrease of the feed-food competition in beef production systems in several regions of Europe. The aim of the project is to identify scenarios for more sustainable beef farming systems, i.e. less competitive with human food systems while remaining viable, liveable and fair. This identification work relies on a participatory approach that includes the stakeholders of the beef sector and the use of the *FarmDyn* modelling tool. This paper focuses on the participatory approach.

We chose to invite stakeholders to be a part of our research because we assume that the decrease of the feed-food competition can lead to a re-design of the whole socio-technical system of beef production. The objective of this approach is therefore to better bridge the gap between science and practice, between research and action, in a transformational goal, although the project is limited to the proposal of scenarios.

In this paper, we describe and discuss both how we implement the participatory design, i.e. the methods we used to include stakeholders in our research, as well as the results this participatory process produces. We also analyze how our approach promotes the intersection of science and practices, focusing on our learning, as researchers, rather than on the learning of the stakeholders. Our purpose is therefore above all reflexive-oriented.

Methods

This paragraph reports on both the methods used to implement the participatory approach (1) and the conceptual frameworks used for the analysis of the data produced and of the participatory design (2).

By stakeholders of the beef sector, we mean breeders, farm advisors, up and downstream value chain actors, public authorities, but also scientists. The latter were the first to be included into our research by participating – through open-ended interviews – in the identification of innovations likely to reduce the feed-food competition. By innovation, we mean:

"The introduction of something new or improved into something that has a well-established character, such as products, processes, marketing or organizational methods. In other words, it means applying ideas, knowledge or practices that are new to a particular context with the purpose of creating positive change that will provide a way to meet needs, take on challenges or seize opportunities. Innovation is generally synonymous with risk-taking" (French, Montiel, et Palmieri 2014; Directorate General for Research and Innovation (European Commission) 2013; Centre National de Ressources Textuelles et Lexicales 2012).

We developed this definition following the interviews with the experts, who questioned the concept of "innovation".

Thanks to these interviews, and a classic literature review (scientific as well as grey literature), we obtained a list of innovations that we then characterized on the basis of the Eco-efficiency – Substitution – Re-design (ESR) approach (Hill et MacRae 1995). This conceptual framework is designed to characterize farmers' transition towards sustainable agriculture following three stages: eco-efficiency (E), substitution (S) and redesign (R) (Estevez, Domon, et Lucas 2000). In our case, efficiency refers to innovations that improve the effectiveness of fodder production or animal feeding practices and limit waste. Substitution refers to the replacement of the part of the feed competing with human food by less competitive feeds. Finally, the re-design stage occurs when the causes of the problem are recognized, allowing to develop solutions at the farm or regional level to modify the system and make it more self-sufficient.

These innovations were then discussed with other stakeholders of the beef sector using the method of focus groups. These focus groups involved breeders, farm advisors and up and downstream value chain actors, i.e. feed manufacturers, actors from genetic selection, veterinarians, cattle traders, slaughterhouses, retailers and consumers' associations[32]. To avoid risk of self-censorship[33], we organized two kinds of focus groups: with breeders and farm advisors on the one hand, with value chain actors on the other hand. The groups were artificial groups (i.e. created by us specifically for the period of our research). We used the snowball-sampling technique to recruit breeders. Farm advisory structures and other organizations were involved as relay-actors. The purposes of the focus groups was to gather the opinions of the participants on feed-food competition in general, and on the innovations identified through literature review and experts' interviews in particular, in order to identify and characterize the barriers and levers to their implementation at the farm, territorial and value chain scale.

To achieve these goals, we used facilitation techniques, namely the moving debate and voting techniques. The moving debate – also called "positioning game" – is a facilitation technique where the facilitator presents a statement or asks a closed-ended question, and participants must position themselves in space according to their opinion (Evrat-Georgel et Kling-Eveillard 2018). The room is divided in two parts: on one side, people who agree with the assertion, on the other side, those who disagree. The middle symbolizes the space for people with no opinion. The facilitator invites each participant to express oneself and explain his/her position/opinion. Other participants can move through space as they hear each other's arguments. As it is experienced as a "game", this technique helps to temper the debate. We used this technique to gather the opinions of the participants on the general objective of reducing feed-food competition in beef farming systems. We also organized votes on the innovations in each focus group. The breeders and advisors could vote for as many innovations as they wanted. They voted in two phases: first,

[32] However, some of them cancelled their participation the D-Day.

[33] Indeed, focus groups require both sufficient social homogeneity but also diversity within the group in order to encourage interactions (Duchesne et Haegel 2004).

the relevance, then the feasibility of the innovations, using labels of different colours (one for the relevance, another one for the feasibility). In the focus group with the value chain actors, we used the technique of Régnier Abacus (Balle-Beganton et Philippe 2018), which we adapted. For each innovation, participants had to choose the degree of their support, ranging from "total support" to "radically opposed", by way of "support", "mixed", "no support", "do not know" and "no answer", each position corresponding to a colour (see below).

The data collected through focus groups were then analysed thanks to the multi-level perspective (MLP), which provides a framework to understand *"how transitions to a new system take place"* (Geels 2006). According to (Geels 2006), the multi-level perspective distinguishes three levels:

The meso-level formed by socio-technical regimes. These regimes *"are actively created and maintained by several social groups"*.

The micro-level formed by technological niches, i.e. *"protected spaces"* and *"incubation rooms" "where it is possible to deviate from the rules in the existing regime […]. Niches provide space to build the social networks that support innovations"*.

The macro-level formed by the socio-technical landscape, *"which refers to aspects of the wider exogenous environment, which affect socio-technical development (e.g. globalization, environmental problems, cultural changes)"*.

These *"three level interact dynamically over time"* (Geels 2006), which leads to transitions and system innovations. The dynamic of the interactions follows four phases:

Emergence of novelties within the micro-level, while problems in the current landscape and regime occur.

Improvement of the novelties by a growing network of actors (i.e. engineers, producers) revolving around them.

Dissemination of the novelties, which compete with the current regime.

Replacement of the old regime by the new technology, *"which is accompanied by changes in wider dimensions of the socio-technical regime"* (Geels 2006).

However, transitions do not occur without difficulties. Indeed, existing regimes generally put up some resistance to change due to inertia, but also to socio-technical lock-in mechanisms and path dependency. According to (Baret et al. 2013) *"lock-in is defined as a situation where a dominant technology prevents the development of alternative trajectories. The origin of lock-in is most often multifactorial, social and technical (we will speak of socio-technical lock-in) and linked to the dependency on the path of most innovations"*.

Finally, we characterized our participatory design based on a recent review by (Lacombe, Couix, et Hazard 2018). In this paper, the authors analyse participatory processes used in research projects aiming at designing innovative farming systems, i.e. agroecological farming systems. They identify five main co-design approaches, i.e. the "de novo design" (1), the "case-study design" (2), the "niche innovation design" (3), the "co-innovation" (4) and the "activity-centered design" (5). Depending on the approach, the role that the farmers play *"can range from simple knowledge providers to co-designers"* (Lacombe, Couix, et Hazard 2018). This analytical framework is built around four questions: who designs and who participates in the co-design? What is the object of the design? Where does the co-design take place and when does it end? How is the design implemented, mainly in terms of knowledge management?

Results

The innovations and their characterization according to the ESR framework

We identified 21 innovations likely to address feed-food competition in beef production systems (see

Table 10). The 21 innovations were sorted, according to the ESR framework.

Table 10 – List of innovations identified to adress feed-food competition and their characterization based on the Eco-Efficiency – Substitution – Re-design (ESR) framework (Hill et MacRae 1995)

	Innovations	ESR characterization
1	Cattle fattening on pastures	R
2	Dynamic rotational grazing	E
3	Alfalfa and red clover as protein supplements in rations for young beef cattle	S
4	Hay dried in barn	S, R
5	Production of fodders through cover crops	E
6-8	Use of by-products coming from the agri-food industry: oil seed cakes used dried stoned olive pomace whey	S
9	Conservation of local pulps and by-products in a single silo	E
10	Use of insect meal as a source of protein in cattle diets	S
11	Use of algae as a substitute for corn or soymeal in the grower and finisher cattle diets	S
12	Crossbreeding (continental breed x breed with an early maturity, more adapted to be fattened under grazing) (e.g. Salers x Angus)	E, S
13	Spring calving for a better use of grass resources	R
14	Genomic selection: measuring and favouring the milk production of suckler cows	E, R
15	Genomic selection for food efficiency	E
16	Terminal crossbreeding with beef breed, on dairy herd, for commercial beef production	E, R
17	Precision livestock farming: connected plate pasture meters	E
18	Precision livestock farming: infrared analysis of fodder	E
19	Integrated crop-livestock systems	R
20	Agroforestry	S, R

21	Limiting meat production to non-competitive feed	R

The opinions of the farmers, advisors and up and down value chain actors on feed-food competition

These innovations were then discussed with farmers, advisors and value chain actors in eight focus groups (three in France, two in Italy, three in Belgium) between September 2018 and February 2019. The focus groups involved 66 participants, half of whom were farmers. Seven focus groups gathered breeders and advisors, one focus group gathered value chain actors[34].

As we mentioned in the introduction, the request for less feed-food competition in beef farming systems comes from society and research. We therefore wanted to gather the opinion of the participants on the object of our research: do they share the objectives of the project? Under what conditions? Through the technique of moving debate, we asked to the stakeholders the following question:

"In the beef production sector, one of the avenues envisaged for more sustainable beef farming systems is to increase the share of resources non-edible by humans in cattle diet. Do you agree with this avenue?"

While most participants agreed with the objective per se (their positions varied from simply "agree" to "totally agree"), they questioned it and, at the same time, questioned the foundations of our research. Indeed, some participants expressed that they felt the project as an additional attack of cattle farming. They raised the following questions in particular: why focus on ruminants farming while feed-food competition is higher in other production systems? (1) Why focus on competition between feed and food in a situation where fuel exerts a pressure - even greater according to some of them - on the production of food and feed? (2) What resources are exactly inedible by humans? (3) They also mentioned the following elements as many pressures on European beef farming systems:

The globalization and the imports: the trade agreement between the Mercosur and the European Union (seen as a threat) was especially mentioned;

The changes in consumption patterns: the growing consumers' preference for minced beef (coming from culled dairy cows) than for "noble pieces" of meat (coming from meat breeds);

The changes in the human-animal relationship: they mentioned in particular the increased visibility in society of anti-speciesism, veganism, and anti-meat activism[35].

Finally, they pointed out the lack of incentives for less feed-food competition (from decision makers, value chain, consumers) and the soil and climate conditions (cattle farming being the only option in some area) as brakes on the decrease in the feed-food competition.

If most participants agreed with the objective of reducing feed-food competition, the means used to this end led to more divergence within and between groups. Indeed, some participants were opposed to the use of by-products (considered as waste or which could conflict with the search for autonomy at farm scale), while others feared that grass-fattening may be done at the expense of performance. Finally, while most participants shared the objective of reducing feed-food competition for the breeding phase, some were sceptical about the fattening phase, especially

[34] Walloon value chain actors (BE).
[35] Several actions carried out by anti-meat activists in France made the headlines at the same time as the focus groups.

considering the carcass conformation standards being in force in the value chain, as expressed in the following excerpt:

"When a young bull comes fat from pasture, I don't say it [editor's note: to the cattle trader]*, I don't brag about it, because the cattle trader will remove it* [editor's note: from the batch]. *He will say: « the fat is not the right colour, the carcass doesn't hold the same way, ...». And it's a practical matter!"* (a Walloon breeder-fattener leading a maize-based system)

We also observed that the reduction of feed-food competition seems rather a secondary benefit of other approaches (such as the search for autonomy, forage efficiency or decrease of the herd) that an objective per se: no participant acts specifically in this direction.

The opinions of the farmers, advisors and value chain actors on the innovations

After presenting them with the list of innovations identified, we asked the participants to express their preference through a vote. Table 11 shows the ranking of the innovations according to their relevance from the breeders and farm advisors point of view. They are sorted from the most relevant to the least relevant. Table 12 shows the ranking of the innovations according to their degree of support by the value chain actors. They are sorted from the most supported to the least supported[36].

In the focus groups with breeders and farm advisors, among the most relevant innovations, none of them really reaches consensus: when there is a consensus within a group, there is not systematically consensus between the groups, and vice versa. The different profiles of the breeders involved can partially explain these divergences[37]. On the other hand, they seem to agree more on the least relevant innovations.

Within the focus group with value chain actors, there is a consensus on more innovations, both among the most supported and least supported innovations. But there are divergences of opinion too.

If we compare the two types of focus groups (i.e. breeders and advisors on the one hand, value chain actors on the other hand) there are also differences: if stakeholders agree on innovations receiving little support or relevance, the same is not true for the other innovations.

Finally, from the point of view of the ESR approach, the vote of the stakeholders does not really seem to have been influenced by the stage to which the innovation refers (E, S or R stage). Indeed, the selected innovations affect all categories, and none of them stands out in particular

[36] The list of innovations put to the vote was not exactly the same in each country and in each focus group: all the innovations were not discussed in all the focus groups.

[37] The breeders involved are either breeders, or fatteners, or breeders-fatteners. Their systems are either mainly grass-based system, or maize-based system. They also belong to conventional or organic farming. This diversity of profiles, combined with different soil and climate conditions, partly explains the variability of breeders' positions on innovations.

Table 11 - Results of the voting sequence in the focus groups with breeders and advisors: relevance of the innovations

Innovations	ESR[38]	Number of votes*	Number of focus group that select this innovation*
Genomic selection for food efficiency	E	15 (n=35)	3 (n=4)
Cattle fattening on pasture	R	13 (n=59)	4 (n=7)
Dynamic rotational grazing	E	12 (n=59)	4 (n=7)
Production of fodder through cover crops	E	10 (n=29)	4 (n=4)
Alfalfa and red clover as protein supplements in rations for young beef cattle	S	10 (n=59)	3 (n=7)
Precision Livestock Farming	E	9 (n=59)	4 (n=7)
Use of by-products coming from the agri-food industries[39]	S	8 (n=59)	5 (n=7)
Genomic selection: favouring the milk production of suckler cows	E,R	6 (n=59)	3 (n=7)
New sources of proteins: insects, algae	S	6 (n=59)	3 (n=7)
Integrated crop-livestock systems	R	5 (n=14)	2 (n=2)
Crossbreeding (continental breed x breed with early maturity) (e.g. Salers x Angus)	E,S	4 (n=59)	3 (n=7)
Terminal crossbreeding (beef breed on dairy herd)	E	2 (n=29)	2 (n=4)
Spring calving	R	2 (n=43)	2 (n=5)
Agroforestry to produce fodders	S, R	2 (n=59)	2 (n=7)
Hay dried in barn	S, R	1 (n=59)	1 (n=7)
Conservation of local pulps and by-products in a single silo	E	1 (n=29)	1 (n=4)
Limiting meat production to non-competitive feed available	R	0 (n=29)	0 (n=4)

* The list of innovations put to the vote was not exactly the same in each country and in each focus group: all the innovations were not discussed in all the focus groups. That explains the variation in the number of individuals and focus groups who participated in the vote.

[38] Characterization of the innovations based on the Eco-Efficiency – Substitution – Re-design (ESR) framework (Hill et MacRae 1995).
[39] The by-products considered differed according to their availability in the region concerned.

Table 12 - Results of the voting sequence in the focus group with value chain actors: degree of support of the innovations (n=7 individuals). Each cell corresponds to a vote. Color code: Dark green = total support; light green = support; yellow = mixed; orange = no support; red = radically opposed; white = do not know.

Innovations	ESR[40]	Degree of support (n=7)						
By-products coming from the agri-food industry: breweries dregs	S	dark green	dark green	dark green	light green	light green	light green	yellow
Alfalfa and red clover as protein supplements	S	dark green	dark green	dark green	light green	light green	light green	white
Genomic selection : favouring the milk production of suckler cows	E, R	dark green	dark green	dark green	light green	light green	light green	white
Genomic selection for feed efficiency	E	dark green	dark green	dark green	light green	light green	yellow	white
Terminal crossbreeding with beef breed on dairy breed	E	dark green	dark green	light green	light green	light green	yellow	yellow
Integrated crop-livestock systems	R	dark green	dark green	light green	light green	yellow	yellow	white
Crossbreeding (continental breed x breed with an early maturity) (e.g. Salers x Angus)	E, S	dark green	light green	light green	light green	yellow	yellow	orange
Cattle fattening on pasture	R	dark green	light green	light green	light green	yellow	yellow	white
Precision livestock farming: infra-red analysis of fodder	E	dark green	light green	light green	light green	yellow	white	white
Precision livestock farming: connected herbometer	E	dark green	light green	light green	light green	yellow	white	white
Dynamic rotational grazing	E	light green	light green	light green	light green	yellow	yellow	white
By-products coming from the agri-food industry: downgraded products (vegetable, milk powder)	S	dark green	light green	light green	yellow	yellow	yellow	yellow
Hay dried in barn	S, R	light green	light green	yellow	yellow	yellow	yellow	white
By-products coming from the agri-food industry: whey	S	light green	light green	yellow	yellow	yellow	yellow	orange
Spring calving	R	light green	light green	yellow	yellow	yellow	orange	white
Algae	S	light green	light green	yellow	yellow	white	white	white
Agroforestry	S, R	dark green	dark green	yellow	red	white	white	white
Conservation of local pulps and by-products in a single silo	E	light green	yellow	yellow	yellow	yellow	white	white
By-products coming from the agri-food industry: process waters	S	dark green	yellow	yellow	yellow	orange	orange	white
Limiting meat production to non-competitive feed	R	yellow	yellow	orange	red	red	red	red
Insects	S	orange	orange	red	red	red	red	white

[40] Characterization of the innovations based on the Eco-Efficiency – Substitution – Re-design (ESR) framework (Hill et MacRae 1995).

The barriers and levers for the innovations uptake

The focus groups also aimed to identify and characterize the barriers and levers to the implementation of the innovations at the farm, territorial and value chain scales. Figure 19 and Figure 20 give an overview of these barriers and levers from the participants' point of view (all innovations combined). The barriers refer to multiple dimensions of the socio-technical regimes for beef production, ranging from the production to the territory, by way of guidance, transformation, distribution, consumption, cattle, culture, regulations and policies. The levers refer to the innovations per se and their potential economic, social and environmental performances, but also to some components in the environment that act as many opportunities.

Figure 19 – Barriers for the innovations' uptake identified by the stakeholders of the beef sector

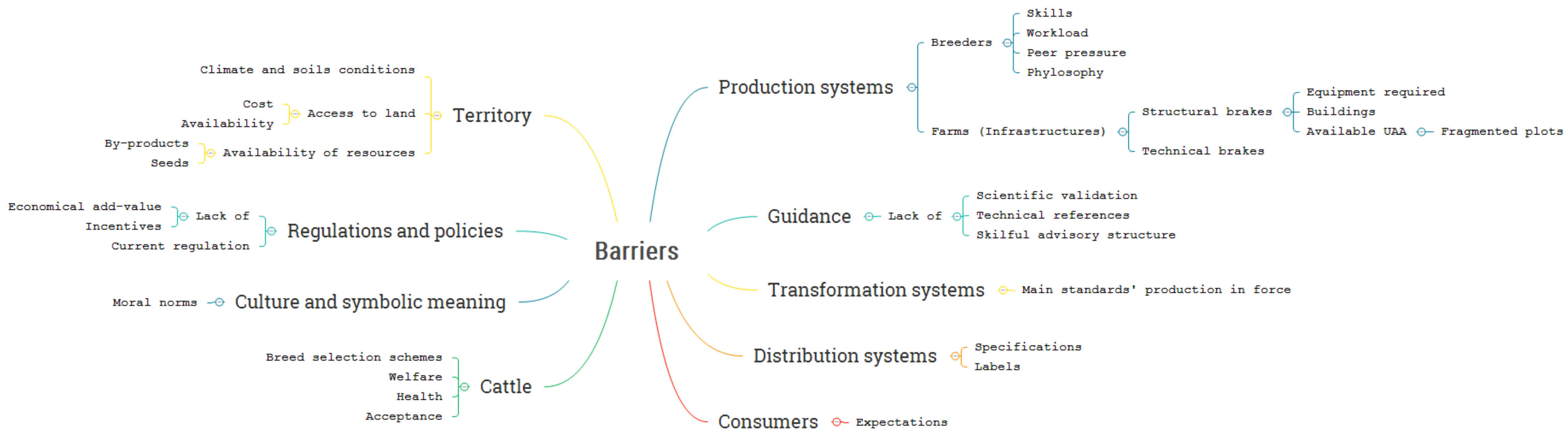
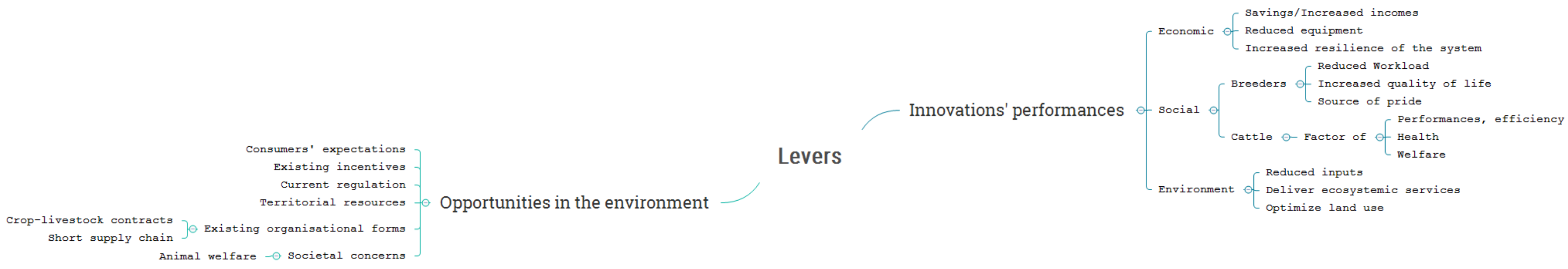


Figure 20 – Levers for the innovations' uptake identified by the stakeholders of the beef sector



Discussion

Dynamics on system innovations

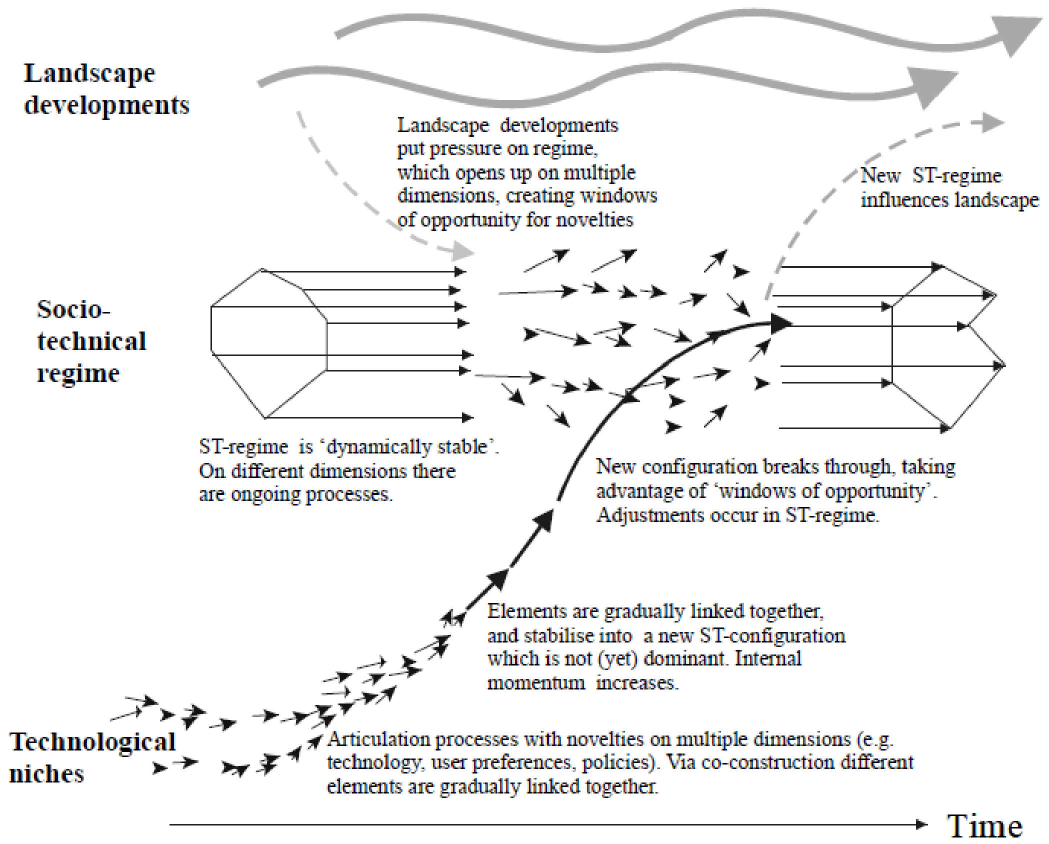
The focus groups allowed us to identify some elements that can be considered as what (Geels 2006) calls *"landscape changes that put pressure on the regime"* (see Figure 21), such as the globalization, the imports of beef meat and trade agreements, the multiple land uses (especially for energy production) that may compete with the production of food and feed, the climate change, or else the resources depletion. Note that the stakeholders also consider the criticisms of beef production systems from the perspective of feed-food competition as a pressure.

Participants also highlighted changes at the regime level, such as changes in food consumption patterns and in human-animal relationships.

These elements are what (Geels 2006) calls *"external circumstances"* that can produce *"windows of opportunity"* when they appear simultaneously, i.e. the conditions necessary for the third phase of the transition, namely the dissemination of the novelties (see above, in the methods part).

On the other hand, the focus groups helped us to identify what (Geels 2006) calls *"internal drivers that* [also] *stimulate the diffusion of innovations",* such as the potential performances of the innovations, but also the links innovations forge with elements of the environment. These links act as many opportunities for their development.

Figure 21 – A dynamic multi-level perspective on system innovations (Geels 2002b: 110) in (Geels 2006)



Conversely, the focus groups also highlighted several socio-technical locks-in, such as the standards in force in the value chain (e.g. the *"S grade ideal"* for the beef carcass conformation and "*the lean-and-tender référentiel"* in force in Belgium (Stassart et Jamar 2008) and the related breed selection schemes and bill of specifications). These locks-in prevent the change from one socio-technical system to another.

All these elements help us to better understand how the socio-technical systems for beef production can change to less feed-food competition systems.

Intersection of science and practice: a reflexive exercise

We encountered some difficulties to sort the innovations according to the ESR framework. Some innovations (e.g. "agroforestry to produce fodders", "crossbreeding", "genomic selection favouring the milk production of suckler cows") refer thus to several stages, because the boundaries between the three stages are often too fuzzy. This is one of the criticisms regularly pointed out about this conceptual framework, i.e. presenting the transition as a succession of distinctly separate stages, when they have to be seen more as overlapping (Brédart et Stassart 2017). We decided to use the ESR approach because it seemed interesting to us to distinguish the transition strategies mobilized by each innovation and to differentiate innovations that are closer to business as usual (i.e. innovations referring to the "E" or even "S" stages) and those that are more disruptive (i.e. innovations referring to the "R" stage). Indeed, the latter are potentially the ones for which support (advice, policies, research) will be the most crucial. If it is true that the barriers and levers that the stakeholders identified for the uptake of the innovations referring to the "R" stage (e.g. "integrated crop-livestock system", "cattle fattening on pasture" or else "spring calving") refer in particular to levels above the farm scale (e.g. standards' production, regulation, ...) – and in this sense need crucial support from a wide range of actors – it is also true for the implementation of innovations referring to the "E" or "S" stages (e.g. "genomic selection for food efficiency", "use of by-products coming from the agri-food industry"). As (Geels 2006) points out, this depicts that *"system innovations are not merely about changes in technical products, but also policy, user practices, infrastructure, industry structures and symbolic meanings, etc."* Therefore, system innovations have to be seen as *"changes from one socio-technical system to another"* (p.165) what implies the support of *"a wide range of actors"* (p.166). In this sense, if the characterization of the innovations thanks to the ESR framework helps us, as researchers, to differentiate between innovations that are closer to business as usual and those that are more disruptive, it seems less effective when proof against practice.

It is maybe partially due to the fact that, from a methodological point of view, the way we identified the innovations was maybe too much "science and technique oriented", i.e. limited to the technical and scientific angles and especially, in both cases, to the agronomic field (the experts met and the literature read). In particular, we should have broadened the profile of the interviewees. Indeed, the concept of innovation is too often limited to a technical sense, even though it takes many forms (organizational, social, political, etc.) (Baret et al. 2013).

The use of the term "innovation" was also probably a mistake, as innovation means "novelty" for most of the stakeholders[41], whereas several innovations identified are clearly not "novelties". This caused disappointment for some participants that consider innovation necessarily as a break.

These elements argue for a more general reflection on science-innovation relationship – and wider society-innovation relationship – and the omnipresent injunction to innovate (Ménissier 2016). This reflection will not, however, be carried out in the context of this paper.

[41] As said in the results' part, some experts met in interviews highlighted the problematic use of the term innovation. We had therefore planned a short sequence in the focus groups aiming to bring out the participants' representation of the innovation. The results of this sequence are not presented in this paper however, as the results' part is already substantial.

Characterization of the participatory design

The object of our research is not exactly the same as in the research projects Lacombe et al. analyse in their review (Lacombe, Couix, et Hazard 2018). Indeed, the authors analyse co-design projects related to the implementation of the principles of agroecology. Moreover, our aims differ, as Lacombe et al. focus on *"the link between a co-design situation and its transformational effects"* (p. 209) from the point of view of the farmers, while the paper at hands focuses on the researchers' learning. However, we can use their analytical framework to characterize the involvement of the stakeholders in our project. Thus, the process we use is clearly research-oriented, not support-oriented. The demand comes from society and research, not from farmers. The goal of the participatory process is to define relevant scenarios of change towards less competitive beef farming systems. The role played by the stakeholders is to express their opinions – about the feed-food competition, about the relevance and feasibility of the innovations we identified and about the scenarios the consortium defines – during indoor workshops. In this sense, the stakeholders are *"knowledge and feedback providers for modelling"* (Lacombe, Couix, et Hazard 2018) (p. 214). The process does not lead directly to a change of their own practices, although this could be, by a reflexive movement. The expected outcome is an assessment of the performance and sustainability of the scenarios to inform decision-makers of the innovations to be supported. The participatory approach ends with this outcome. The design is therefore neither action, nor learning oriented – although we may pursue these aspects in a later project. In this sense, the participatory design we used comes up to what the authors call "case study design".

Considerations on the methods and techniques used

The focus groups really contributed to the participatory nature of our approach. They allowed stakeholders to express themselves, without being trapped by top-down knowledge. However the recruitment of the breeders was time and energy consuming, as well as the transcript of the exchanges and the analysis. The use of this technique in the context of participatory research is therefore particularly interesting, but the resources needed to achieve it (time, skills, availability of team members, budget, ...) should not be underestimated, as it can be, when focus groups are reduced to a simple meeting of people (Barbour et Kitzinger 1998; Duchesne et Haegel 2004; Baribeau 2010).

Concerning the moving debate, this technique allowed us to go beyond components that could have "paralysed" the discussions later on by reappearing systematically throughout the debates, in an untimely manner. Furthermore, allowing the participants to express themselves on the subject of our research gave them the feeling of a "real" exchange[42] (i.e. on equal terms), where, as scientists, we did not come as "holders of knowledge", in a top-down logic.

Finally, between the two voting techniques used, our preference is for the Régnier Abacus. Indeed, while voting with coloured labels is easier and faster to implement, the Régnier Abacus' technique gives an overview of all the participants' opinion for each innovation. It also allows reducing social desirability bias.

Conclusion

In this paper, we show how a participatory approach can help researchers to better understand the dynamics of system innovations. Starting from a list of innovations likely to reduce the feed-food competition in European beef farming systems mainly focused on technical and scientific

[42] Several participants pointed out this aspect at the end of the focus groups.

aspects, the involvement of the stakeholders of the beef sector provides us an overview of the windows of opportunity as well as of the lock-in at work.

The participatory approach also allows researchers to learn through a reflective exercise. It provides a better understanding of how the methods used and the way the research is led impact the results obtained.

However, the role of the stakeholders is limited to the supply of knowledge and feedback for modelling, as the research is not action-oriented. The participatory process ends with the proposal of scenarios addressed to decision-makers.

The results presented in this paper serve as a foundation for the definition of these scenarios and their modelling by the members of the consortium. The next step of the participatory process is to discuss these scenarios and the results of their simulations (i.e. performance and sustainability assessment) with the stakeholders previously involved through restitution workshops.

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HOW TO FACE THE CHALLENGE OF ANALYSING THE RESULTS OF ON FARM EXPERIMENT TO SUPPORT PARTICIPATORY RESEARCH SCHEMES?

Gyselynck W.[a], Jamar D.[a], Pitchugina E.[a], Planchon V.[a], Denargel M.[b],

Dierickx S.[c], San Martin G.[d], Stilmant D.[d]

[a] Walloon Agronomic Reaserch Center (CRA-W)
[b] INAGRO VZW
[c] Greenotec asbl
[d] Walloon Agronomic Reaserch Center (CRA-W)

INTRODUCTION

The agricultural sector faces several major drawbacks linked to its dependency toward nonrenewable resources (such as oil and phosphorus) (Van Vuuren et al. 2010), its impact on the environment (such as biodiversity loss, soil erosion, water pollution and greenhouse gas emissions) (Soule et al. 1990) and on the social system (such as land grabbing, difficult working conditions, animal wellbeing) (Altieri 2002; Rulli et al. 2013).

Several production systems, based on agroecological principles (Altieri 2018), such as organic agriculture (Seufert et al. 2012), conservation agriculture (Hobbs et al. 2007), agroforestry (Dupraz and Fabien 2008) and permaculture (Ferguson and Lovell 2014), aim to answer at least to some of those concerns. Agroecology is a holistic production system pointed out as a response to climate change and the global economic and social instability context that can be adopted by large-scale farmers historically engaged in a productionist system (Altieri 2018).

For the farmers this technical shift toward agroecology is difficult due to its knowledge-intensive nature, its relatively uncertain results and the requirement of local references (de Tourdonnet et al. 2013). For the scientist, this shift implies a new posture of agronomic research from top-down input-based research and development to bottom-up co-constructed holistic experiments with a scope not only on the production of new agronomic knowledge but also on the assistance of the farmers in their transition toward low-input agroecological systems. This requires getting closer to the realities of the field and developing participatory research schemes with groups of farmers.

This collaboration often leads to difficulties. Indeed the farmers can see formal experimental designs as impractical and too far from their ground realities (Piepho et al. 2011; de Tourdonnet et al. 2013). This highlights the need for scientists to explore new experimental schemes that can combine both of their and the farmers' needs.

In this context, we have been conducting since 2019 a participatory agronomic experiment based on the priorities and the expectations of a group of farmers in Wallonia (Belgium). The general principle is to conduct a personalized systemic experimentation in one field of each farmer of the group in order to assist them in knowledge production of locally adapted breakthrough techniques (such as direct seeding, permanent living mulch use, cash crop association and so on).

Even though this methodology enables us to assist much more efficiently the farmers in their transition toward agroecological systems, drawing general conclusions from this approach, in order to spread those innovations to a large number of farms in the Walloon area, seems much more difficult. Indeed, due to the limitations in the experimental design (Table 14) and the uniqueness of each field experiment in the different farms, common statistical tools cannot be used. However, the opportunity of developing robust and novel knowledge bases from the breakthrough techniques implemented by the farmers is not overlooked. The aim of this article is to display the methodological difficulties encountered by the scientists, especially concerning the future statistical analyses of the results and our answers to overcome those difficulties.

THE CHALLENGES OF ON FARM EXPERIMENTS

The term “on farm experiment” (OFE) refers to an agronomic experiment set up on a farm (as opposed to one set up in an experimental station). This generic term hides a lot of variability concerning stakeholders (Lightfoot and Barker 1988), objectives (Catalogna et al. 2018), experimental design (Rivière et al. 2015; Catalogna et al. 2018), time and spatial scale (Lightfoot and Barker 1988), data collection and indicators used (Toffolini et al. 2015; Catalogna et al. 2018) and results assessment (Hoffmann et al. 2007). Several examples of OFE are displayed in Table 13. This table highlights the main differences between several experimental designs that can be set up on a farm. Specifically those differences are linked to the objective, scales (spatial and time), use of indicators, results assessment and diffusion of the experiment’s results.

When both farmers and scientists are involved in an OFE, differences between the rigorousness of formal experimentation methods and the priorities of the farmer co-defining and/or hosting the experiment can lead to difficulties and unease on both sides.

On the one hand, it is not unusual for farmers to feel scientific experimental designs as an additional source of workload leading to unenforceable results. Indeed, they are usually set up with highly specific material, using multiple small plots or strips and covering modalities that are not always in line with the farmers’ expectations (Lightfoot and Barker 1988; Hoffmann et al. 2007). Furthermore, the farmers might get frustrated by the lack of flexibility of the experimental process through time if new information comes up or if the experiment shows that it is going to be a failure (Catalogna et al. 2018). Another source of frustration can come from the fact that the differences between the experimental treatments often affect only a single factor (for example fertilization type or weed management strategy) in order to highlight a causal link and does not affect the whole management system.

On the other hand, the scientists might experience difficulties analysing the results due to suboptimal experimental design that cannot allow the assessment of a phenomenon or robust statistical analyses (Perrett 2006; Lawes and Bramley 2012). Indeed, by coping with the ground reality of heavy farm motorization, it might be difficult to get a formal and complete experimental design. This led to the creation of alternate experimental designs such as strip trials (Piepho et al. 2011; Lawes and Bramley 2012) and mother-baby design (Rivière et al. 2015) or alternative statistical tools (Perrett 2006). Another common problem for the scientist is attempting to assess too many treatments and/or factors in order to answer the needs for innovation of the farmers and not being able to follow all those variating factors (Hoffmann et al. 2007).

Apart from the experimental design, other differences between the scientists and the farmers’ points of view are linked to their primary objectives and the diffusion of the results. The objective of the farmers usually being very tangible (better economic performance for example) while the primary objective of the scientists usually is to explore additional dimensions or performances, aside from the economic one (Hoffmann et al. 2007). Likewise, the results of OFE will be spread formally by the scientist through articles and conferences (usually out of reach for most of the farmers) while farmers read technical articles and/or use informal channels such as discussion with peers or social media (de Tourdonnet et al. 2013).

Nonetheless, OFE and collaboration between farmers and scientists are a cornerstone of agroecological transition (Navarrete et al. 2018; Catalogna et al. 2018). Indeed the difficulties of combining the formal scientific method and the ground-oriented approach of the farmers highlights their complementarity in agronomic research. Apart from helping the farmer in OFE design (Catalogna et al. 2018), the scientists can provide technical assistance and help famers with similar objectives to connect with each other or with rural development organisms (Navarrete et al. 2018, de Tourdonnet et al. 2013). Meanwhile, the farmers enable the design of innovations and technical itineraries with a more systemic view and a better knowledge of the realities of their systems (de Tourdonnet et al. 2013).

Table 13: Examples of on farm experiments.

	Randomized Complete Block Design (RCBD)	**Strip-trial design** (Piepho et al. 2011)	**Mother-baby design** (Rivière et al. 2015)	**Farmer's experiment** (Catalogna et al. 2018)
Experimental design	Optimal : Balanced Randomized Replicated With a control Few variable factor(s)	Sub-optimal Balanced Replicated With a control Few variable factor(s)	Sub-optimal Partially replicated With a control Few variable factor(s)	Exploratory Priority to conveniency No replication Often without control Several variating factors
Objective(s)	Technology impact on production aspect(s) (yield, workload and so on)	Technology impact on production aspect(s) (yield, workload and so on)	Usually plant breeding	Systemic innovation
Spatial scale	A few dozen square metres per treatment Experimentation in other field(s) optional	Several hundred square metres per treatment Experimentation in other field(s) optional	A few dozen square metres per treatment Usually experimentation in other farms	Several hundred square metres per treatment or more Usually only one field
Time scale	Short: one cropping season or less	Short: one cropping season or less	Long: more than one cropping season	Short and/or long
Indicators	Figures Usually only technical and/or environmental aspect(s)	Figures Usually only technical and/or environmental aspect(s)	Figures Usually only technical and/or environmental aspect(s)	Figures optional Multi criterion (social, economic)
Results assessment	Statistical analyses	Statistical analyses	Statistical analyses	Figures comparison Personal appreciation
Results diffusion	Formal Scientific journals Conferences	Formal Scientific journals Conferences	Formal Scientific journals Conferences Technical journal	Formal Technical journal Informal Discussion with peers Social media

THE FARMERS' PLOTS NETWORK SYSTEMIC EXPERIMENTATION (FPNSE)

Complaints on previous experimentation methodologies (mainly strip trials (Piepho et al. 2011; Lawes and Bramley 2012)) and the applicability of the results emerged from a Walloon (Belgium) group of farmers implementing agroecological practices on their farm. The scientists and advisors in charge of the group coordination thus developed a new experimentation process based on the farmers' priorities and expectations.

The originality of this experiment is that it puts the individual farmers and their practices at the core of the experimental process. The main objective being to get as close as possible of their individual priorities and realities to substantially help them in their transition toward low-input and low-disturbance agroecological practices.

The experiment is based on a specific crop rotation, co-developed with each farmer for at least three seasons on a given field. This is done through one or several meeting(s) between each farmer and one or several technical advisor(s). Firstly, the objectives of the farmers are discussed (for example, stop using glyphosate-based herbicides or implementing crop associations). Then the current and conceivable crops of the farm are listed. Afterward, a field is chosen based on its size (at least two hectares), the fact that it has a unique history (same crops and same management) and consistent soil texture and structure. At last, a crop rotation is co-developed with the farmer with a scope on checking his previously defined objectives. This rotation is flexible through time and can be changed in concertation between all the stakeholders. It is also discussed with other farmers during group meetings.

On one part of the field, the farmer will carry out its crops as usual with well-mastered techniques (called the *control site*) while on the other part of the field (called the *impact site*, around one hectare of surface area) the farmer will experiment new techniques. On this experimental area, except for the cultivated crop, the whole management system can potentially be impacted (fertilization, pest regulation, soil management, and so on) with a scope on reducing soil disturbance and external input use. An example is shown in Figure 22. The chosen field (with a red border) has a surface area of 10.8 hectares. The impact site, on the east, has a surface area of around 1.5 hectares (with a green border). This is the only place where a differentiated treatment will be applied. The yellow bordered rectangle is the part of the control site where measurement will be done in order to compare the usual practices with the experimented techniques.

As the only variating factors between the impact and the control sites are linked to the differentiated management strategy, all the other factors being consistent (weather conditions, field history, soil texture and initial structure, farmers, main cultivated crops), we consider that the only cause of variation between the impact and control sites are due to the differentiated management strategies over the years.

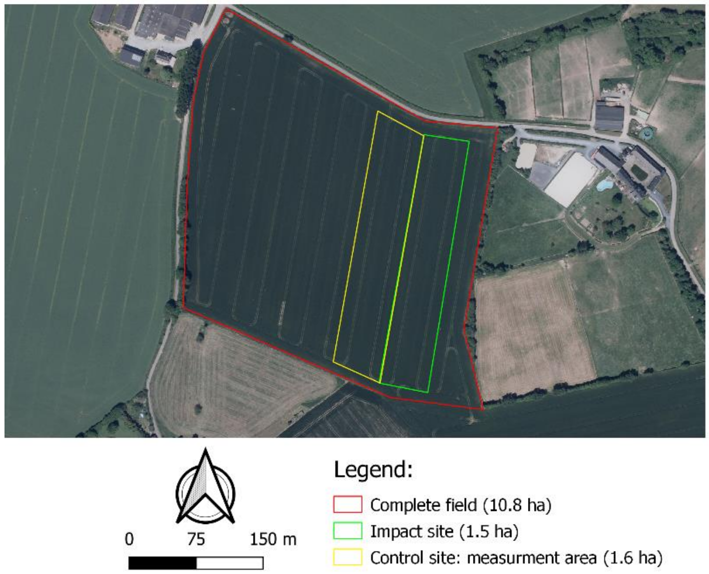

Figure 22: Example of a field part of the FPNSE. Note that the experimental design takes into account the usual tractor pathway of the farmer to limit any additional workload.

At the farm level, our experiment is unreplicated and unrandomized. This means that we cannot estimate the variance of each management strategy (through subsampling we can only estimate the variance inside a plot). Furthermore, the lack of randomization can lead to the incorporation of any potential pattern in the results (Plant 2007). However, this risk is limited by a careful choice of the impact and control sites in collaboration with the farmers.

These design limitations are quite common in the field of environmental monitoring and impact assessment (Eberhardt and Thomas 1991; Smith et al. 1993; Underwood 1994). Therefore, the methodologies used in those research fields, mainly the Before-After-Control-impact (BACI) design and its variations, have been an inspiration source for our experiment.

In its simplest form, BACI designs are composed of two sites and two time periods. The set of sites is composed of one impact site supposed to have been affected by an external source (such as a stream from which water is pumped upstream by a power plant then released downstream, warmer than before, which might have an impact on the local fauna, for example on fish laying behaviour (Smith et al. 1993)) and a control site which has not been affected. The choice of the studied sites is critical. Firstly, the impact site has to be chosen so that the impact, if existing, can be observed. Secondly, the control site must answer several powerful hypotheses. Indeed, it has to be similar to the impact site but it cannot be affected by the external source. However, all and every external factors have to be similar between the impact and control sites through time. Following the same example, the weather conditions, flow variations, fishing intensity, and so on must be similar for both sites. Another way to present the link between the two sites is that one must be able to consider them as paired, except for the assessed effect of the external source. The set of periods is simply composed of one before and one after period. Keeping on with the same example, the before period is when the power plant is not active yet while the after period begins when the plant starts electricity production (and water pumping).

The BACI design has been the subject of substantive discussions (Stewart-Oaten et al. 1986; Underwood 1991, 1992, 1994; Stewart-Oaten and Bence 2001; Stewart-oaten 2014) and has been shown to be sensitive to the methodology of analysis (Smith et al. 1993; McDonald et al. 2000; Smokorowski and Randall 2017).

Therefore, multiple variations of the initial design have been suggested (Downes 2008). Thus, one applying this kind of experimental design should be careful in the analysis and interpretation of the results.

Several major differences between BACI design (and its variations) and our experiment can be spotted. The first one is that two clear time periods (before and after) are not defined in our case where crop growth and succession are continuous processes. The second one is that the hypothesis that the impact and control sites are paired is easier to accept than in most environmental monitoring experiments because the fields share the same soil, history, weather conditions and crops. At last, in our experiment, multiple control and impact sites are monitored (one for each farm) and the experimental measures are done at the same time (at least for one set of impact and control sites). Thus our experimental design gets closer to the MBACIP design (Multiple BACI Paired) (Downes 2008) which is composed of several impact and control sites that are considered paired in time.

The cultivated crops and techniques experimented in the field will vary among farmers following their personal objectives and constraints. Thus, this experimental design has two distinct levels. Firstly, the farm or field level, with the individual co-constructed crop rotations and the comparison between the impact and control sites of each field. Secondly, the group level were farmers and scientists will be able to exchange about the individual innovations and compare the results of several similar experiments (for example the use of a strip-till for the implementation of a spring crop). The main characteristics of this experiment are summarized in Table 14.

This experimental design enables the farmers to experiment novel and uncertain agricultural techniques while limiting risks (because the experimentation is conducted on a relatively small area and the potential financial risk is shared with the scientists) and to compare those techniques to their usual management system. The scope of those techniques is quite large. It is composed of:

Low disturbance soil management techniques such as strip-till or direct seeding;

early implementation of winter crop;

crop association for multiple harvests or environmental services (nitrogen and carbon sequestration, soil fissuring, and so on);

use of a perennial living cover crop through (part of) the rotation;

crop or cover crop grazing.

Note that those techniques are usually combined on the experimental fields.

Table 14: Main characteristics of the FPNSE

Farm or field level	Group level
Long term and continuous process	
Unreplicated: one control and one impact sites.	**Unreplicated**: a different treatment is potentially applied at each location (the management techniques are decided with each farmer). However, there is some consistency in the experimented techniques.
Unrandomized: the sites are chosen with the farmer according to his usual tractor pathway in the field (Figure 22).	**Balanced**: Each experimental field has one control and one impact site
Several and simultaneous variating factor between the impact and control sites.	**Inhomogeneous blocks**. The surface area of each control and impact sites are different
Paired observations: the control and impact sites share the same history (crops and management techniques), environment (weather conditions, soil) and cultivated crops. Thus, we assume that any potential difference(s) between the impact and control area will be caused only by the new management practices over the years.	**Unpaired**: Across farms, the fields do not share a common history or a specific management system

ANALYSES OF THE EXPERIMENTAL RESULTS OF THE FPNSE

The experimental results are to be analysed in order to differentiate and communicate on innovations that show some potential from those seeming to be inefficient.

To achieve that, different analyses will be performed. Firstly, a multivariate analysis will be conducted on the different sites (impact and control) across the farms and years in order to link agricultural practices to performance indicators (environmental, social and economic). The objective of this analysis is exploratory and will allow us to highlight potential interconnections between practices and some of the performance indicators recorded. Secondly, based on these observations, the impact significance of the practices implemented across several farms will be studied. This will be done using a generalized linear mixed model (GLMM). Thirdly, in order to produce more readable results (for a public without a scientific background) and to double-check our previous conclusions, a complementary Bayesian Markov chain Monte Carlo (MCMC) (Conner et al. 2016) approach shall be used on the highlighted interconnections. Those analyses are presented in Table 15 and detailed below.

Those last two analyses (GLMM and MCMC) will use the results of the experiments at the group (or subgroup) level. They imply that the same variables and indicators will be measured through the different farms, sites and crop cycles of the study. Thus, it is essential to define those criteria beforehand to insure good recording by the farmers and appropriate measurement by the scientists.

Table 15: Synthesis of the different analyses that will be conducted in the study

	Multivariate analysis	Generalized linear mixed model (GLMM)	Bayesian Markov chain Monte Carlo (MCMC)
Aim	Exploratory	Impact assessment	Results vulgarization and validation
Expected results	Correlation structure between practices and performances indicators highlighting indicators sensitive to the practices	Significance level of the site parameter for each analysis	Distribution of the ratio between the impact and control site for each indicators
Number of analyses	One or several if needed	Several, one for each practice/indicator correlation	Several one for each GLMM
Analyses based on	Every crop cycle across the farms	Pairs highlighted by the multivariate analysis	Pairs analysed in the GLMM
Farms and years considered as random factors	No	Yes	Depending on the methodology

LINKING THE PRACTICES TO PERFORMANCE INDICATORS: MULTIVARIATE ANALYSIS

The objective of this analysis is to explore the potential relations between the agricultural practices on the impact and control sites and environmental, social and economic performance indicators. The multivariate analysis will help us to clear the view for further statistical work. It might also enable us to implement the experimented practices into a typology.

In order to optimize the ratio between the number of individuals and the number of variables while keeping consistent individuals to limit the number of NA's, we suggest that the blocking factors of the database be (1) the farm, (2) the site (impact or control), (3) the year of crop implementation, (4) the implementation order of the crop on the field for the given year (considering cover crops on equal footing as any commercial/forage crop). For example, an individual could consist of a cover crop sowed after a spring crop in 2019 on the impact site (I) of farm Y thus giving us the individual Y_I_2019_2. These blocking factors would not be active variables of the multivariate analysis.

One drawback of this approach is that some individuals will cover a longer time period than others (for example winter crops sowed in autumn) and some will cover seasons completely different than others (for example winter cover crops and spring crops). A possibility would be to conduct several separated analyses, one for each type of crop (spring, winter, frost sensible cover crop and so on). We should therefore be careful on the power of relations that will be produced by the analysis, especially for environmental indicators, which might be more sensible to a difference in the duration of a crop or its growth period.

Apart from the blocking factors, the database would also be composed of variables linked to agricultural practices and performance indicators (social, environmental and economic). Those variables are detailed below and shown in Table 16.

The variables describing the agricultural practices would cover the type of crop, the modalities of soil preparation, the use of inputs and so on. For this exploratory analysis, those variables would exclusively be factorial or binary. The variables covering the agricultural practices could potentially all be active in the multivariate analysis.

The variables used to characterize performances indicators would be continuous and linked to the workload (hours of work for soil preparation, weeding, and so on), the accounting of the plots (turnover, costs, and so on) and to environmental observations (on soil organic matter, biodiversity and so on). Note that contrary to most of the other variables, environmental observations can be done several times during the crop cycle. This means that a temporal aspect could be added for those indicators.

As shown in Table 16, the multivariate analysis would have to combine factorial (the agricultural practices) and continuous (the performance indicators) variables. From there, several options are available. On the one hand, the variables could be kept as they are, using a methodology that allows the combination of those two types of variables in the multivariate analysis. We would use either a factorial analysis of mixed data (FAMD) or a multiple factor analysis (MFA). The latter would allow splitting variables in groups in order to assess the influence of any given group (for example, combine all the variables linked to external inputs such as fertilizer, pesticides, and so on). On the other hand, the continuous variables (performance indicators) could be transformed into categorical ones using appropriate thresholds. From this derived database exclusively composed of categorical variables, a multiple correspondence analysis (MCA) could be performed. The robustness and loss of information of this transformation would have to be assessed.

The expected results are the same as for any multivariate analyses. Specifically, we hope to link breakthrough agricultural practices to performance indicators, enabling us to study these correlations in detail further on. A complementary result would be a typology of practices based on their impact on the production system.

Table 16: Illustration of the description of one crop in the database used for the multivariate analysis

	Example of variables	Main variable type	Potentially active in the analysis
Block description	Farm, site, year and order of implementation in the year	Factorial	No
Practices	Crop type, soil preparation modalities, phytosanitary product use, and so on	Factorial	Yes
Primary variables for performance indicators computation	Workload, cost and turnover, site area, environmental observations, and so on	Continuous	No
Performance indicators (derived from the primary variables)	Land and work productivity, gross margin per hectare, aggregate stability and so on	Continuous	Yes

ASSESSING THE IMPACT OF SELECTED PRACTICES: GENERALIZED LINEAR MIXED MODEL (GLMM)

Hopefully, the results of the multivariate analysis presented above will highlight correlations between agricultural practices and performance indicators. The next step will be to assess a global and somewhat consistent impact of those specific practices on performance indicators across several crops, farms and seasons during the experiment. This will be done through a Generalized Linear Mixed Model (GLMM).

As stated before, due to the design of our experiment, we suppose that the only source of variation between the impact and control sites of a field is the differentiated technical management of the crops. Note that over the crops cycles, this effect could become more and more substantial. Hence, the effect of the time period since the beginning of the experiment on selected indicators could also be assessed.

In our analysis, the studied individuals would be a subsample of the ones used in the multivariate analysis detailed above. They would share similar innovative practices, for example the use of a specific soil preparation technique. The blocking factors used to build up the database would be the same as for the multivariate analysis: the farm, the site, the year and order of implementation. If the assessed indicator can be measured more than once during the crop cycle, the time of measurement (such as before sowing or after harvest) could be a complementary blocking factor or integrated in the statistical model.

The usual analyses conducted to compare means between groups is an analysis of variance (ANOVA). This analysis has been dismissed because it cannot handle several variating random factors, which would have limited the scope of the analysis. Furthermore, we would not have been able to take any other fixed effect into account (such as the cultivated crop). This led us to consider the use of a generalized linear mixed model (GLMM) as the best approach as it would enable us to use the farms and the years of implementation as random factors and be able to add any other fixed effects if needed. This is also the methodology advised by McDonald et al. (2000) because this model does not have any normality assumption. For variables that can be measured several times during a crop cycle, this would enable us to assess the interaction parameter between the site (control or impact) and the time of measurement.

Due to the design limitations of our experiment, it is likely that we would use a method to adjust the p-value of our statistical tests as it is the case when comparing means of unreplicated experiments (Perrett 2006; Plant 2007). Several methodologies are available and further reflexion is needed to choose the most appropriate one (Smyth and Verbyla 1999; Hothorn et al. 2008; Finos et al. 2010).

COMMUNICATING THE RESULTS TO THE FARMERS THROUGH BAYESIAN MARKOV CHAIN MONTE CARLO (MCMC)

One of the main priorities of the experiment is to assist farmers in their transition toward low-input agroecological systems. One part of this task is the personal counsel and experiences acquired during the course of the study with the differentiated treatment of the impact site. This includes continuous feedback on what has been measured in the farmer's field (for example cover crop biomass or crop germination rate). The other side of this assistance is to help farmers share their experiences between them through the organization of group meetings, field trips and the synthesis of the experiments' results. The methodology of this synthesis has been largely discussed in the former sections. However, the understanding of those results requires specific statistic notions out of reach for most of the population (including farmers and policy-makers). This issue is often disregarded in OFE and can lead farmers to have scepticism toward scientific results (de Tourdonnet et al. 2013).

In order to produce results that farmers can understand themselves (as opposed to the scientific team displaying the significant effects of practices to passive individuals), we would use a Bayesian approach to present the results to the farmers and the general public. Indeed, using Bayesian Markov chain Monte Carlo (MCMC) we can provide more readable results such as the probability of a twenty percent or more increase (or decrease) in a performance indicator (Conner et al. 2016). Thus, the results are presented as a distribution of the relative change of the indicator between the impact and control site. This could be done either to estimate a distribution of the ratio between the impact and control site (Conner et al. 2016) or to estimate a distribution of the site parameter of the GLMM presented above (Gamerman 1998; Christensen et al. 2006). Furthermore, this distribution could enable us to double-check the results from the GLMM reducing the risks for types I and II errors (Conner et al. 2016).

CONCLUSION

This article presents a novel experimental design for on farm experiments based on the farmers' priorities and expectations, mainly convenience and the ability to experiment a complex and systemic crop management strategy. It aims the adoption by the farmers of new agroecological and locally suited techniques as well as robust agronomical knowledge production. It is based on a co-constructed crop rotation, specific to each farmer, of at least three years. Thus, the rotations and experimented techniques differ from farmers to farmers based on their objectives. This rotation is implemented on a part of a larger field, the rest of the field being sowed with the same crops but managed with well-mastered techniques and acts as a control. This experimental design is unreplicated and unrandomized. Those design limitations bring difficulties in the analysis of the field results and robust knowledge production.

These difficulties will be overcome using methodologies inspired from environmental monitoring studies where those design limitations are more common. However, the experiences in this field show that a careful analysis of the results is required. In our case, this analysis is foreseen as threefold. Firstly, a multivariate analysis for exploratory purposed, aimed to highlight performance indicators sensitive to the agricultural practices. Secondly, a generalized linear mixed model aimed to assess the impact significance of the former highlighted practices. Thirdly, a Bayesian Markov chain Monte Carlo would be conducted to double-check our previous results and to produce results that do not imply any statistical knowledge so that farmers can more easily get to grips with them.

This paper shows that ground oriented and locally suited agronomic knowledge can potentially be produced in close collaboration with farmers, allowing the scientists to spread innovations much more efficiently to the agricultural production sector than with conventional scientific channel such as formal publication.

ACKNOWLEDGEMENTS

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AN ASSESSMENT OF THE PRACTICAL POTENTIAL AND LEVEL OF PARTICIPATORY RESEARCH NEEDED TO MEET CATCHMENT SCALE CLIMATE CHANGE OBJECTIVES

Chris Stoate[a], Jeremy Biggs[b], Penny Williams[b], and Colin Brown[c]

[a] GWCT Allerton Project
[b] Freshwater Habitats Trust
[c] University of York

Abstract

We assess three approaches to climate change related catchment management for their efficacy, potential for participatory research approaches, and wider practical application in central England. Creation of clean water ponds are intended to isolate aquatic biodiversity from elevated eutrophication associated with climate change, permeable timber dams are intended to reduce downstream flood risk, and improved soil management is intended to achieve multiple benefits. These approaches vary in their potential public and private benefits, but tend to be associated with climate change adaptation, rather than mitigation. We conclude that, while traditional top-down approaches to researcher engagement with farmers might be appropriate for activities such as clean water pond creation, earlier, more active engagement is important to designing and siting permeable dams to deliver public benefits outside the study area. For soil management, where there is a complex integration of multiple public and private benefits, climate change adaptation and mitigation, and wide variation between soils, topographies and farming knowledges and cultures, early and genuine participatory approaches are essential.

Introduction

Climate change presents multiple challenges to lowland agricultural environments in the UK. Lower summer rainfall and higher temperatures may increase concentrations of phosphorus and other nutrients and pollutants in freshwaters, increasing eutrophication and ecological degradation beyond current levels. More frequent and intense winter storms are expected to increase downstream flood risk, both through higher rates of surface runoff from headwaters, and through increased soil erosion and sedimentation of drainage channels. As well as increased rates of runoff and erosion, agricultural soils can be expected to continue the current trend for increased levels of compaction, inhibiting crop performance and reducing the period in which field operations and livestock grazing can be carried out without further accelerating this trajectory.

In this paper, we explore three management approaches to meeting environmental objectives for catchment management: creation of clean water ponds for biodiversity, permeable dams for flood risk management, and soil management to meet multiple objectives. We discuss the potential wider application of these measures in the context of their role in climate change adaptation and mitigation, and their potential for public or private benefits. This context is presented conceptually in Figure 1. We anticipate that the acceptance of management approaches by farmers will increase along the continuum from public to private benefits and from mitigation to adaptation. Understanding of these relationships would help to inform future catchment management policy and support for land managers.

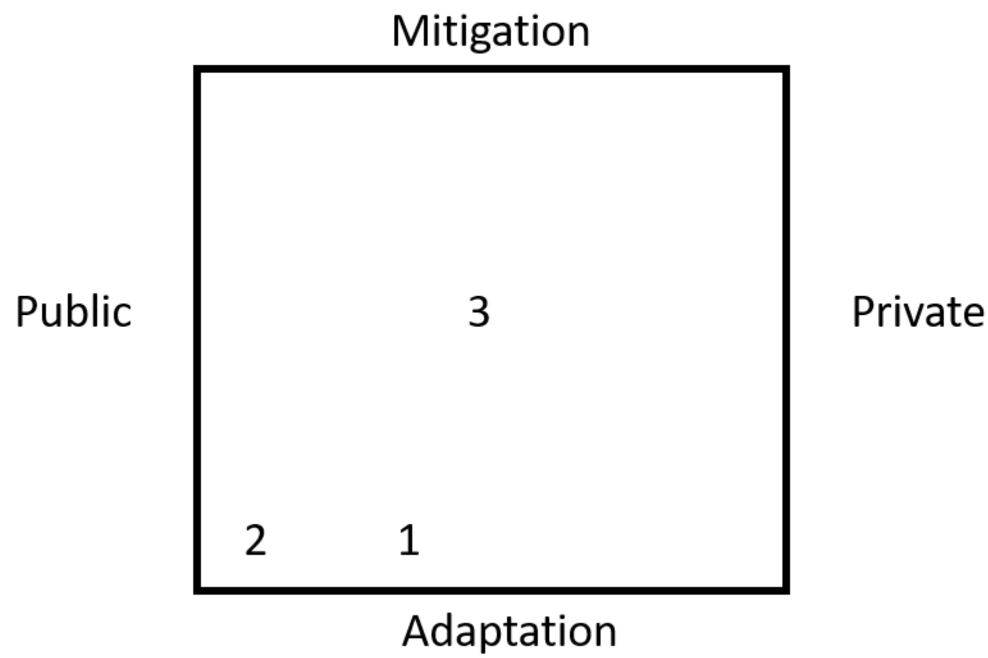

Figure 1. Climate change engagement matrix representing the continuum between mitigation and adaptation, and between public and private benefits. 1. Clean water ponds. 2. Permeable dams for managing downstream flood risk. 3. Multiple objectives for arable soils.

Traditionally, research engagement with farmers is regarded as either top-down (state or researcher led) or bottom up (citizen or farmer led), based on Arnstein's (1969) 'Ladder of participation'. More recently, Keen, Brown & Dyball (2005) have argued that some citizens prefer to stay on the lower rungs of informing and consulting, while Cook, Kesby, Fazey, & Spray (2013) have questioned whether the higher rungs necessarily lead to power-sharing by citizens. Reed et al. (2017) suggest that the choice of participatory method needs to take account of the situation, making some approaches more suitable in certain situations, and suggest a "Wheel of Participation" as an alternative metaphor that accommodates these complexities.

The research described in this paper is based on the 'Water Friendly Farming' project, a landscape scale (3,000 ha) BACI (Before, After, Control, Impact) experiment in the headwaters of the river Welland in central England. The study area is located 6km from the Allerton Project research and demonstration farm which carries out research into a wide range of agri-environmental issues on its own 333ha farm.

In conventional terms, the Water Friendly Farming project was initiated in 2010 as a 'top-down' research project, with for example, the farming community being defined by the hydrological boundaries of the three headwater catchments. Initial engagement between researchers and farmers was limited to broad discussion about the objectives of the project and obtaining agreement for involvement in principle. Different levels of more active participation have been introduced into the project and we discuss some of them here.

The objectives of the research described in this paper are therefore to:

assess the performance of physical measures for meeting climate change related catchment management objectives at the landscape scale introduce and explore a participatory research approach to involve farmers in the research and decision-making process

assess the implications of the above for future wider application of the measures being considered

We first describe the study area, then the specific objectives and activities associated with the three management approaches, and finally discuss the project in relation to the three objectives stated above.

The study area

The Water Friendly Farming project aims to test the efficacy of a range of measures to increase landscape scale aquatic biodiversity, improve water quality, and reduce downstream flood risk, while maintaining or improving agricultural productivity and profitability (Biggs et al., 2016). The soils are mainly Hanslope and Ragdale clays and the farming systems are arable, mixed arable and livestock, and grazing livestock systems (mainly sheep and beef cattle). Farm size varies considerably, as do tenure arrangements, with some areas being owner occupied, and others adopting a range of tenure arrangements including both long and short-term lets, joint ventures and contract farming agreements. The height above sea level ranges from 123m to 216m, the topography is undulating, and the annual rainfall is around 650mm. Further details for each headwater catchment are provided in Table 1.

The project started in 2010 with exploratory water quality and aquatic ecology data collection. 2012 to 2014 represented a three-year baseline period in which data were collected across the three headwaters. Almost continuous monitoring of stream depth and flow, total phosphorus, total nitrogen, and suspended sediment has been carried out at the base of each of the three catchments, with additional pesticide concentration data being collected through four autumn/winter periods (for further details of methods see Villamizar et al., 2020). Ecological survey data (aquatic macrophytes and macro-invertebrates) were collected annually from 360 ditch, stream and pond sites across the 3,000-ha study area in the baseline period, and 420 sites subsequently, to accommodate newly created features (for further details of methods see Williams et al., in press).

Table 1. *Land use details and management approaches adopted in the three headwater catchments*

Landuse	Barkby control catchment	Eye catchment	Stonton Catchment
Catchment area	9.6Km2	10.6Km2	9.4Km2
Arable	37%	45%	44%
Grass	52%	42%	41%
Woodland	7%	9%	10%
Settlements & other minor landuses	4%	4%	5%
Number of farmers	7	14	8
Management approaches discussed in this paper			
Clean water ponds	n/a		X
Permeable dams	n/a	X	
Soil management	n/a	X	X

A range of measures was introduced into the two 'treatment' headwaters (Stonton and Eye Brook) from 2014. These measures included maintaining existing riparian buffer strips, fencing livestock away from streams, installation of sediment settlement ponds at a range of scales, introduction of small woody debris dams and other site-specific measures. Here we focus on the creation of clean water ponds in the 'Stonton' catchment, the creation of permeable dams in the 'Eye Brook' catchment and a range of supporting measures to improve soil function across both catchments. The third, 'Barkby' catchment, served as a control in which no measures were introduced.

Management approaches

Clean water ponds

Elevated phosphorus concentrations in freshwater result from both agricultural runoff and domestic sources such as septic tanks and rural sewage treatment works, and even at concentrations below 100µg/L, have been shown locally to have a substantial impact on the local aquatic ecology (Jarvie et al., 2010). Sewage treatment works in the Water Friendly Farming study area are the largest single contributor to elevated phosphorus concentrations in each of the headwater catchments (Biggs et al., 2016). Climate change related concentration of these domestic sources associated, or increased frequency and intensity of runoff from agricultural sources would increase the threat to aquatic ecosystems.

In 2014, twenty clean water ponds were created in the Stonton catchment. These are off-line waterbodies (not connected to streams or ditches) located in parts of the landscape where they fill with unpolluted surface-water or groundwater. Suitable sites for locating the ponds were identified by researchers, based on the characteristics of the micro-catchments draining into them and the sites proposed were discussed with the relevant farmers. As these ponds were located in relatively unproductive areas such as open areas of woodland plantations, rough grassland and corners of relatiely low grade pasture fields, farmers were content to accommodate all the proposed ponds on their farms. Some required them to be fenced to exclude livestock while others did not.

All catchments saw a background decline in aquatic macrophyte species richness during the nine-year survey period, with a mean species loss of 1% pa, and a rare species loss of c2% pa (Williams et al., in press). The addition of clean-water ponds brought substantial catchment benefits, increasing the number of wetland plant species by 27% after five years, and the number of rare plant species by 190%. Populations of spatially-restricted species also increased.

The creation of clean-water ponds that are hydrologically isolated from the main stream network may hold considerable potential as a tool to help stem, and even reverse, ongoing declines in freshwater plant biodiversity associated with landsape scale eutrophication. Although farmers were unaware of the specific biodiversity benefits of introducing clean water ponds to their land, those involved recognised the conservation value in broad terms and were positive about having such ponds on unproductive parts of their land. Summary results of the biological surveys for each farm, and overall findings have been shared with farmers.

Permeable dams for flood risk management

As part of an increasing trend towards 'Natural Flood Management' to complement traditional engineered flood defense approaches, permeable timber dams have been introduced across several river basins but there is limited evaluation of their efficacy or the issues influencing farmers' attitudes to, or knowledge associated with their installation.

We used hydrological modelling to inform the potential distribution of dam sites within the study area. Stream water depth was monitored at the base of the headwater catchments every 15 minutes and then converted into stream flow (m^3/s) using a flow rating curve generated for the catchment. The Soil and Water Assessment Tool (SWAT; Arnold et al., 1998) was used to simulate stream flow. SWAT is a physically based hydrology and water quality model, designed to estimate impacts of land management practices on water quality in complex watersheds. SWAT divides the catchment area into sub-catchments and each of them is further divided into hydrological response units which are defined as areas of land with the same soil, land use, slope and management which are assumed to behave similarly in the model (Neitsch et al., 2005). This process formed the basis for the identification of 51 sites for permeable timber dams to manage storm water flow within the headwater and attenuate downstream flood peaks.

On the ground, locations in ditches and streams were selected carefully to optimise water storage while avoiding impeding flow from field drain outlets and waterlogging adjacent arable land. The focus was on in-channel water storage, but opportunities for temporary flooding of adjacent land were also explored. A map showing the location of these sites was used as a focus for one-to-one discussions with farmers about their acceptability or otherwise.

Following discussion with farmers, permeable dams were ultimately built at 30 sites, and many of these were not in the exact locations identified by the hydrological modelling. In some cases, it proved to be impractical to build the dams because the ground was too soft, steep or wooded to permit access for construction equipment. More often, sites were not acceptable to farmers because of conerns about waterlogging productive land or land used for vehicle access in winter. Farmers made the point that flooded land would remain waterlogged for a period after the flood event, so that it would not be possible to drive on or manage the land without causing damage to soil structure and this would have a negative impact on trafficability and grass or crop performance.

Although farmers accepted the concept of introducing permeable dams on their land to reduce downstream flood risk, there was little sense of ownership and there were concerns about maintenance and liability. Although, in this case, researchers accepted responsibility for these, this issue is of wider concern outside a research project. On the other hand, at one site, a larger area of ground was made available to receive flood water than had been assumed in the initial modelling process. This highlights the varying responses of individual farmers to proposals to install permable dams, and the need to recognize factors other than simply production forgone, in itself something that is difficult to predict because of climate change uncertainty.

A contractor based within the catchment was employed to build the dams so as to optimise engagement within the catchment community. The dams were of simple construction, and created with mainly local materials. Standard timber (mainly larch) cordwood was the main component, held in place with tanalised fence posts and steel cable. A tree trunk formed the base of each dam, spanning the full width of the channel, to ensure that winter base flow was not impeded.

Assuming optimal distribution of permable dams across the entire headwater catchment, the initial modelling estimated a peak daily flow reduction of 20%. Actual implementation of dams is currently being evaluated but is estimated to be equivalent to or in excess of this reduction, with for example a 25% reduction for one in two year storm events. The interim results therefore suggest that the dam site selection by farmers, and the reduced number adopted, has not compromised flood risk management objectives, relative to the adoption of dam sites identified by hydrological modelling.

Multiple objectives for arable soils

Poorly functioning soils result in erosion and sedimentation of watercourses, reducing biodiversity and increasing flood risk, while also increasing nutrient and pesticide transport to water. Such soils also increase grass weed populations and reduce crop rooting capacity, nutrient cycling and uptake by crops. In conversations with researchers, farmers have highlighted the negative impacts of poor soil function on both their own businesses and environmental and societal issues such as water quality, aquatic ecology and flood risk.

Farmers have been keen to address this issue in order to improve the performance and sustainability of their businesses but identified a lack of evidence-based information relating specifically to clay soils as a barrier to enabling them to do so. Following discussions with farmers, a highly respected advisor with expertise in soil management and a range of cultivation and drilling equipment was identified by the farmers and one-to-one advisory visits were arranged for each arable farmer at the end of the baseline period in 2015. Each of the farmers visited was positive about the visit and found the discussion useful.

After four years, farmers reported no improvement in soil function in terms of improved crop performance. In fact, although most of the period experienced lower than average rainfall, exceptionally heavy autumn and winter rains in 2019 completely waterlogged sols and prevented drilling of crops. Base of catchment water quality monitoring recorded no improvement in suspended sediment or associated phosphorus over the study period. Repeat visits by the same advisor as in 2015 will be carried out in 2020 to identify barriers to changes in soil management and communicate research requirements identified by farmers to researchers.

In 2017, farmers were involved in two activities which were intended to bring farmer knowledge and concerns closer to research that was relevant specifically to their circumstances. These are described more fully by Villamizar et al. (2020) and Stoate et al. (2019).

Farmers had expressed concern about the potential withdrawal or restricted use of a herbicide used to control black-grass (*Alopecurus myosuroides*), a competitive grass weed that is difficult to control. The regulatory threat to the herbicide arises from the transport to water adsorbed to soil particles eroded from arable land and regular exceedance in watercourses of the statutory 0.1µg/L limit set for drinking water supply. The herbicide is therefore linked to broader catchment management objectives and provides a common theme for discussion between farmers, researchers and catchment managers.

Farmers were invited to consider a number of approaches to soil and crop rotation management that may help them to reduce the loss of herbicide to water, and to suggest additional approaches themselves. In terms of soil management, these included a better understanding of compaction within fields, access to local soil moisture data to inform timing of management decisions, and a reduction in cultivation intensity, including a change to direct drilling. The participating farmers were already attempting to reduce cultivation intensity in at least one stage in their crop rotation.

A workshop involving a facilitator, a researcher, three catchment farmers and an agro-chemical company representative was held. The aim of the workshop was to enable discussion of the various management options. This involved farmers considering the future potential of these approaches, based in some cases on their own experience of them, and in others on evidence presented at the workshop in the form of hydrological modelling results, soil moisture data and compaction maps. The full discussion was recorded and later transcribed. Qualitative, textual data from the transcript were analysed through an inductive approach involving manual coding of the text and identification of the commonly occurring themes as these emerged across the participants (Villamizar et al., 2020).

Compaction mapping was regarded as being useful but farmers raised the question of who would pay for this to be carried out. One farmer already used a simple assessment of compaction to guide his soil management decisions. Farmers considered that the sharing of local soil moisture data could be useful but felt that this was difficult to judge without actually trying it.

Whilst the farmers were generally encouraged by their results with reduced cultivation techniques, they thought that the main barrier to a full direct drilling system on clay soils is the lengthy transition period where there is a significant drop in yield. The transition period may be a significant barrier to adopting direct drilling. There was concern that there is no considered government advice about how to proceed with conversion and one farmer drew the contrast between good husbandry of soils, and the life of a government, which is similar to the length of a normal rotation, and regretted that this prevents governments from implementing a long-term view for agriculture.

In the second initiative, interested farmers were involved, along with members of the wider local farming community, in the prioritisation of soil management research topics that would be relevant to them as part of the SoilCare project www.soilcare-project.eu . An initial meeting was held to discuss the broad issues, both positive and negative, associated with local soil management. A problem tree was used to identify problems, causes of those problems, and possible approaches to address them. A list of management practices was drawn up as potential topics for research.

At a second meeting, summaries of the management practices were provided and a critical discussion of the management practices was then held. Information was summarised on flip charts for each management practice and these provided a focus for discussion within small groups of stakeholders. Post-it notes were used to enable participants to contribute additional information individually. Based on these, a matrix was then drawn up listing the most relevant criteria for scoring the six management practices. Participants were then each given ten sticky dots to allocate to the management practices against the selected criteria.

This resulted in five management practices with similar scores, but enabled one with a lower score to be dropped from further consideration. The two highest ranking management practices (direct drilling and cover crops) were not considered further as they were already the subject of research at the Allerton Project's research and demonstration farm. Three other management practices - compaction alleviation, grass leys, and anaerobic digestate as a soil amendment - were taken forward as the topics for research within the SoilCare project. The digestate amendment could not be followed up for technical and regulatory reasons, but replicated experiments were set up to test different methods of compaction alleviation, and modern deep-rooting grass ley cultivars. The results of these experiments will be shared with farmers participating in the Water Friendly Farming project, and the wider farming community to inform future management and in order to capture feedback from particpants.

Discussion

Performance of physical measures

The introduction of clean water ponds into the agricultural landscape achieved its objective for increasing landscape scale biodiversity, as demonstrated by the data for aquatic plants.

Interim results suggest that the introduction of permeable timber dams into the stream achieved its objective of reducing downstream flood risk by reducing the base of catchment flood peak in excess of 20%.

Water quality data have not been fully analysed but the most recent results and observations indicate that there has been little or no improvement in water quality in terms of nutrients and suspended sediment since the introduction of physical measures to address this issue in 2015. Farmers continue to report crop yields that are compromised by poor soil health and function, and waterlogged soils in autumn 2019 prevented drilling of crops.

Participatory research with farmers

The level of engagement between researchers and farmers varied across the three approaches described in this paper. For the introduction of clean water ponds, the involvement of farmers in the decision-making process was minimal and could be regarded simply as consultation associated with a top-down approach on Arnstein's (1969) Ladder of Participation. This level of engagement between researchers and farmers fails to meet most of the criteria for successful outcomes defined by Reed et al. (2017). Despite this, all the proposed ponds were created in the locations that were selected by researchers and achieved the objective of improving landscape scale aquatic biodiversity, while also being acceptable to farmers. Both private and public benefits of pond creation were achieved. In fact, early engagement with farmers might have resulted in greater priority being given to private benefits such as fish ponds or duck flight ponds for shooting which would have been acceptable to farmers but would not have resulted in the biodiversity benefits achieved.

Farmer engagement for construction of permeable timber dams resulted in the rejection of several sites and the re-siting of many dams to locations that were better aligned with farmers' priorities. Although flow data are not currently fully analysed, initial indications are that this change in the siting of dams from those identified by the hydrological modelling to sites that are consistent with the flood risk management objectives, while also meeting farmers' criteria, resulted in equally effective flood risk reduction. Arguably, it might have been equally or more effective to start the process with the involvement of farmers so as to incorporate their local knowledge and values into decision making, prior to hydrological modelling. However, even taking this approach, the objectives remain driven by the delivery of public goods outside the study area, rather than the interests, concerns, knowledge or cultural values of farmers within it.

The complexity associated with soil management, combining private and public benefits, and both climate change adaptation and mitigation, requires much closer involvement of the farmers. We have adopted two structured processes for a more participatory approach. Stoate et al. (2019) evaluated these in relation to the criteria for beneficial outcomes defined by Reed et al. (2017). The criteria comprise 'Context' (challenging or conducive), Design (hierarchical and closed or systematic, transparent and structured), 'Power' (power dynamic unmanaged or managed), and 'Scalar fit' (late and poorly matched or early and well matched to spatial and temporal scale). Each criterion was awarded a score on a five-point scale. The two activities score relatively highly against these criteria, with the exception of the herbicide one for 'Context' as the participant community was defined by the hydrological boundary rather than by criteria that were formulated by the farmers themselves. Two of the five management practices identified as research priorities by farmers in the SoilCare project were already the subject of research at the Allerton project farm, suggesting good alignment of priorities between farmers and researchers.

The three activities reported in this paper therefore vary considerably in the extent to which they could be regarded as being participatory, involving genuine knowledge exchange between farmers and researchers and co-design of continuing activities.

Implications for wider application

We have reported on three approaches which address the impacts of climate change on water quality, aquatic biodiversity, flood risk and crop production in agricultural headwaters. Creation of clean water ponds has very clear biodiversity benefits. It has little impact on the productive land and can enhance the landscape and its inherent interest in a way that is acceptable to farmers. In-channel permeable dams are similarly outside the productive area but the storage of water on adjacent land has the potential to reduce agricultural production, both directly while under water, and indirectly as subsequent waterlogging reduces the period in which the land can be grazed, used for vehicle access, or worked by arable machinery. There is considerable scope for debate around the payments that might be made to farmers to deliver societal benefits in terms of flood risk management given the uncertainties associated with direct impacts on production, associated indirect impacts, and realized benefits in terms of reduced downstream damage to property. Where payments to farmers are based on expected reductions in downstream flood risk and quantifiable damage to property, that uncertainty increases further. Farmers also expressed concerns about maintenance costs, and liability for negative consequences that might arise, either on-site or downstream in the case of dam collapse.

Clean water ponds and permeable dams for flood risk management are clearly adaptation measures providing societal benefits, with clean water ponds also being accepted by farmers as inherent features of their farmland landscape (Figure 1). However, reducing intensity or frequency of cultivation is both an adaptation and a potential mitigation measure. Reduced soil disturbance can have advantages in terms of societal environmental, social and economic benefits, while also benefiting soil function from an agricultural perspective, potentially contributing to enhanced economic performance of farms, but there are clear barriers to adoption, and potential costs, at least on clay soils. Government payments to farmers, such as through agri-environment schemes, are also made more problematic where there are potential associated benefits to individual businesses alongside wider societal benefits. In addition, the relative costs and benefits will vary considerably between farms across a range of soil types, farming systems, topographies, and landscape configuration.

There are other benefits associated with reduced soil disturbance through direct drilling or incorporation of grass leys into the rotation, in that there is potential for carbon sequestration in the soil profile (Mangalassery et al., 2015). The full scale of this is not yet adequately understood, but it highlights another important consideration in terms of the measures adopted to address climate change. Each of the approaches discussed in this paper is concerned with climate change adaptation, and there is a considerable need to increase the emphasis on mitigation, and to identify synergies between adaptation and mitigation.

Catchment management practices that contribute to climate change mitigation are strongly societal rather than private benefits and consequently positioned in the top left of Figure 1. As such they require an offsetting market or government support to encourage adoption. There is also a need to identify opportunities for funding from individuals or businesses to carry out management practices that deliver private benefits alongside public ones, but public and private interests are not always complementary. To use an example from earlier in the paper, clean water ponds that are stocked with fish to obtain an income would have low biodiversity value. The lack of state support for soil carbon sequestration because of potential economic benefits to participating farm businesses is a perverse consequence of the public/private dichotomy.

Conclusions

While our findings demonstrate that some simple measures can address some objectives for delivery of societal benefits, our research in a working agricultural landscape also highlights the economic and political constraints that characterize the trade-offs between public and private goods and services. Economic pressures, potentially heightened considerably by the UK's withdrawal from the EU, increasingly threaten smaller farms, favouring large-scale contracting and short-term planning and accentuating diversity in farming cultures and socio-economic circumstances. A top-down consultation approach to researcher engagement with farmers may meet some simple objectives successfully. However, the complexity associated with interacting public and private interests, and the need to meet climate change adaptation and mitigation simultaneously, require a genuine participatory approach that is co-designed by farmers and researchers. Such an approach needs to recognise the cultural, political and socio-economic diversity of both farming and research communities.

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REDUCING PESTICIDE USE IN VINEYARDS. EVIDENCE FROM THE ANALYSIS OF THE FRENCH DEPHY-NETWORK

FOUILLET Esther[1], DELIERE Laurent[2], CHARTIER Nicolas[3], MUNIER-JOLAIN Nicolas[4], CORTEL Sébastien[5], RAPIDEL Bruno[6,7], MEROT Anne[1]

[1]INRAE, CIRAD, Institut Agro, CHEAM-IAMM, France
[2] INRAE, Bordeaux Sciences Agro, SAVE, UE Vigne Bordeaux, France
[3] Institut de l'Elevage-Agrapole, France
[4] INRAE, UMR 1347 Agroécologie, France
[5] Chambre d'Agriculture Savoie-Mont-Blanc, France
[6] CIRAD, UMR ABSys, France
[7] ABSys, Univ Montpellier, CIHEAM-IAMM, CIRAD, INRAE, Institut Agro, France

Abstract: High quantities of pesticide are applied on vineyard. Transition towards low pesticide farming systems is a key issue to improve viticulture sustainability. Farmers have to gradually change their practices to engage in this transition. A large number of agroecological practices are already existing but farmers can encounter obstacles during their implementation.

This work aims at analysing the pesticide use evolution during transition towards low pesticide farming systems and identify some management options mobilized by winegrowers. To understand the diversity of pathways taken towards agroecological transition, we characterized different types of pesticide use trajectories.

We analysed the data from 244 cropping systems engaged in a network of French demonstration farms, DEPHY-Farm network, created to promote and assess the implementation of practices to reduce the pesticide use. The network provides data over a 10-year period across 12 winegrowing regions. To assess pesticide use, we used the Treatment Frequency Index (TFI) and focused on TFI trajectories. We described the TFI trajectory of each farm using six indicators: the initial TFI and final TFI, the intensity of the TFI decrease, two idicators of potential rupture and the slope. A Principal Component Analysis followed by an Ascendant Hierarchical Clustering were performed to build a typology of pesticide use trajectories. In addition, we performed a survey to identify, for each type of pesticide use trajectories, the levers implemented by winegrowers.

Our results showed that cropping systems experienced a pesticide reduction of 33% in average related to the decrease of fungicide use. Three types of pesticide use trajectories were identified : the first type represents farms with a high initial TFI and an important reduction of TFI. The second type corresponds to farms with a low TFI when entering the network and that reduced it progressively. The last type represents farms with low initial TFI and without significant pesticide use evolution.

Depending on the trajectory type, the intensity and the type of changes in fungicides applications and biocontrol used were different. From the surveys, 76 levers implemented by the winegrowers were recorded. The main levers implemented are related to the dose reduction, choice of the product, stop of herbicides and optimisation of spraying. The changes were characterized according to the ESR framework. Cluster 2 Farm mostly redesigned their cropping system while Cluster 3 Farms mostly implemented levers based on a gain on Efficiency. The context of the farm impacted changes in practices.

ASSESSMENT OF THE RESILIENCE OF FARMING SYSTEMS IN THE SAÏSS PLAIN, MOROCCO

Hossard L[a], Ricote-Gonzalez E[b], Fadlaoui A[c], Belhouchette H[d]

[a] UMR0951 Innovation, INRA, Univ. Montpellier, France
[b] Institut Agronomique Méditerranéen de Montpellier, France
[c] Institut National de la Recherche Agromique de Meknès, Morocco
[d] Institut Agronomique Méditerranéen de Montpellier, France

Abstract: The Mediterranean region is expected to become a hotspot for the impacts of climate change, with high vulnerability to global change. The major challenge is therefore making agricultural food production systems resilient to climate and market shocks (Rivington et al. 2007). Resilience can be defined as the capacity of a system to buffer shocks while maintaining its structure and function (Walker et al. 2004). Focusing on the farm scale, several studies used modelling tools to analyze the resilience of farming systems (e.g., Souissi et al. 2018), however with little involvement of stakeholders when designing scenarios and in resilience impact assessments.

Accordingly, a participatory approach was set up in the Saïs plain in Morocco with the objectives of (1) designing, with stakeholders, the possible future state of different typical farm types under major drivers of change, and (2) qualitatively assessing their resilience. This approach combined different steps: (1) characterizing the structure and performance of current farm types using literature and stakeholders' and farmers' interviews, (2) defining and selecting the main regional and specific drivers of change per farm type, (3) building cognitive maps for current and future state of each farm type according to drivers, (4) characterizing performances of future farm types, and (5) evaluating their resilience. Steps 2, 3 and 4 were achieved with a strong involvement of stakeholders via collective meetings. The indicators of the resilience assessment were defined based on literature, expert interviews and collective meetings with stakeholders. These indicators expressed different types of capitals (land, workforce, financial), public policies, market and water access.

Four representative farm types were selected: highly irrigated predominantly vegetable farms (F1), monocropping rainfed cereals farms (F2), partially irrigated cereal-legume farms (F3) and mostly irrigated fruit-tree-vegetables farms(F4). Climate change was identified as a main driver of change for F2 and F3 whereas access to irrigation water was identified for F1 and F4. According to these expected changes, stakeholders designed adaptation strategies based on the promotion of more diversified systems. Based on the resilience indicators, stakeholders identified F4 and F2 as the most and the least resilient farms, respectively. Overall, this qualitative approach provided relatively different results than previous modelling studies for the same area, thus highlighting the important role of local stakeholders in promoting adaptation strategies against global change.

Jana Zscheischler, Sebastian Rogga

Leibniz Centre for Agricultural Landscape Research, Germany.

Abstract: Many sustainability problems are connected to land use and there is a high sense of urgency for socio-technological change and transformation of current land use practices. In this context, many scholars have emphasised the vital role of designing and steering efficient innovation processes (e.g. Elzen et al. 2004, Schot & Geels 2008).

However, envisaged sustainability innovations differ from other types of innovations. They serve long-term societal goals but mostly lack direct marketing or commercialisation potential. Since management of land is highly regulated in many countries of the world, land management innovations have to take regulation compliance into account. It is deeply embedded into socio-ecological systems and thus frequently contradicts with social practices, regulations and existing infrastructure.

As it is still weakly understood how transformation and socio-technological change in the specific field of sustainable land use and management can be effectively governed and supported, the aim of this talk is to contribute to this knowledge gap. We will present findings from a comparative case study on transdisciplinary innovation research projects from Germany that sought for solutions towards more sustainable land management (SLM) practices. After the introduction of a theoretical framework that supports capturing the specific nature of innovations for sustainable land management, the presentation examines i) the characterisation, leverage points and socio-technical imaginations of innovations for SLM, ii) approaches to manage the innovation processes, and iii) interactions with persisting rules, structures and networks.

Results show that innovations for SLM start with diverse problem framings, emerge from distinct action fields and reflect various socio-technical imaginaries that predetermine trajectories of transition. Furthermore, there is a broad variety of innovation types focussing on different leverage points. All projects applied multi-actor approaches to facilitate reflexive processes of learning and cognitive reframing, optimising the innovation, and interacting with persisting structures and communities.

THE CUMULATIVE TRADITION OF DECISION SUPPORT SYSTEMS RESEARCH: NEW PERSPECTIVES ON SUCCESS

Julie Ingram

Countryside & Community Research Institute, University of Gloucestershire, UK

Introduction

The opportunities and challenges of agricultural Decision Support Systems (DSS)[43] in connecting science and practice are well rehearsed in the academic literature. The focus has mainly been on issues of poor uptake by practitioners. These have been problematised and theorised from different perspectives, largely in relation to the epistemological gap between the hard and soft approaches respectively of science and practice. Given the rapidly changing context in agriculture (social, technological, environmental, institutional) it seems a good time to re appraise the role of DSS and ask questions about their future development and relevance.

The history and philosophy of agricultural DSS has been well documented (Power (2003). Analysis dating back to the discipline of information systems (IS) includes the study of both the social and technical aspects of the use of information technology for decision making and problem solving (Lyytinen, 1987). This body of work supports the view that there is little evidence of uptake or sustained usage, a failure seen to be consistent across all organisations and industries (Newman *et al.*, 2000). As a result DSS have been subject to close scrutiny in a number of reviews internationally (Matthews *et al.*, 2006). Collectively scholars have addressed the question: why are the expectations for DSS usage rarely realised and how can this challenge be addressed? Over time they have built up an extensive understanding of why the optimism for DSS amongst the scientific community does not match the evidence of practitioner usage. There are a corpus of work documenting key factors to enable functioning and sustained DSSs. These date from Little (1970) who identified criteria for functioning Information Systems[44]: robustness, ease of control, simplicity, and completeness of relevant detail and have been revisited by several researchers since (e.g. Rose et al., 2018). The importance of incorporating user input through participatory DSS development has also been recognised with developers soliciting user-feedback about tool performance and ease of use (Ingram et al., 2016; Rose et al., 2018). The value of involving users in genuine co-design (Cerf et al 2012; Berthet et al., 2018; Prost et al., 2012; Volk *et al.* (2010);understanding farmers' situated knowledge (Lundström and Lindblom, 2018); and acknowledging farmers' different decision-making styles (Jørgensen et al 2007), have also been identified as important in improving the usability of DSS.

However, research still tends to focus on implementation issues, performance and uptake, with less attention being paid to questioning the assumptions underpinning DSS, the institutional context, the impact and learning achieved and how to assess it. For this reason, according to McCown (2002), DSS are in danger of being relegated to history without an adequate understanding of reasons for its market failure.

In Australia (and to some extent New Zealand) the evolutionary process of crop model based DSS in agriculture has been extensively reviewed and documented (Woodward *et al.*, 2008) with periodic questioning and reflection which has brought about considerable collective learning and reorientation in tool development. This is an evolving and dynamic domain, as agronomic understanding advances, new technologies appear, and new perspectives emerge, and farming demographics change, each prompting

[43] Decision Support Systems (DSS) and Decision Support Tools (DST) are sometimes used interchangeably. DSS are computer-aided management systems which are typically based on scientific models developed with the purpose of enhancing farmer decision-making. They are often developed into DST. DSS is used in this paper to refer to both system and tool.

[44] Information Systems preceded and preshaped the era of the agricultural DSS (McCown 2002).

further analysis and questioning the relevance of DSS. As Hayman et al (2003) noted in 2003 the "unfolding history of DSS in Australian dryland farming systems provides an interesting case study of the challenges facing agricultural scientists intervening in the world of farm management decisions". This work offers a nuanced understanding of the reasons for limitations in DSS.

This paper aims to explore these developments through a critical review of the DSS literature with particular reference to how a cumulative tradition around DSS has emerged in Australia, and aims to advance theoretical development by introducing this new lens for analysis. The paper is a 'perspective paper' drawing on the literature and personal communications with researchers in Australia as part of an OECD Research Fellowship (2019).

Agricultural Decision Support Systems

The format of decision support depends on the extent of data aggregation and analysis, ranging from simple monitoring and alerts, online calculators to sophisticated models that provide scenarios for, or assess the effects of, different management options. In this paper we refer to the latter which are called DSS[45]. Meinke *et al.* (2001), refers to all DSS as 'normative' approaches of simulation based information provision, including software products and dissemination of such information via printed or Web-based media. Agricultural DSS are however mostly computer and internet-based information systems defined as typically software applications commonly based on scientific models describing various biophysical processes in farming systems and the response to varying management practices (Jakku and Thorburn, 2010). Lynch (2003) called these systems "intelligent support systems". These DSS are usually based on an understanding derived from a statistical- and/or process-based analysis of factors affecting crop outcomes such as yield (Stone and Hochman, 2004).

Over the last 40 years, significant resources have been devoted to the development of computer-based decision support systems (DSS) derived from cropping systems models (such as APSIM). Grain production is inextricably linked to the climate in Australia, and dryland farmers in particular encounter a high level of risk and uncertainty in their agronomic decisions. DSS (with particular reference to plant available water in the soil) have aimed to support their decisions in this context (Freebairn, et al., 2018). DSS development in Australia has been funded, principally via public sector research initiatives (Federal and State Government) with external funding from the Grains Research and Development Corporation, (supported by producers via levies plus matching funds from the Federal Government).

Reflecting on DSS: what has been learned?

Extracting lessons from experience

As Woodward (2008) notes, the history of model based intervention in agriculture has been notably charted and analysed in a series of papers (Hayman, 2004; Nguyen *et al.*, 2006). Overall this literature can be characterised as reflective and formative, addressing the accumulated evidence that most DSS fail in the agricultural market place. Periodically authors suggest it is time for a reappraisal, or a reinvention, or as Cox (1996), who is highly critical, remarked, a "need to pause and think about current levels of R&D investment in information technology to support the management of agricultural production systems". Collectively this literature refers to the lessons that have been learnt through R&D (e.g. Pannell, 1996), Newman (2000) described the process of DSS development as "learning as we go", and Nelson remarks "while early expectations of computerised decision support systems (DSS) as the connecting vehicle between research and practice have gone mostly unrealised, some lessons have emerged from the attempts". Hochman et

[45] Models (the mathematical representation of a system) are distinguished from DSS (interfaces through which users access knowledge from a model).

al. (2009) refer to the Yield Prophet DSS as being grounded in the learning from 18 years of exploring model-based decision support with Australian dryland farmers. Stone and Hochman (2004) ask “have we been asking the right questions?” and go on to say “ We don't see DSS as a lost cause, provided that scientists learn hard-won lessons from their collective achievements and failures”. McCown (2002) aim to improve understanding so that researchers “don’t naively repeating earlier mistakes” While McCown et al. (2009) refer to “extracting learnings from experiences” and aim to interpret the rich set of experiences from the FARMSCAPE project, in ways that are meaningful for future action (or inaction). These observations follow previous earlier reflective and comprehensive accounts: EPIPRE (Zadoks, 1989) and CALEX-Cotton (Plant, 1997; Goodell et al., 1993).

Drawing on these experiences the literature also commonly refers to an ‘emerging consensus’ about how to tackle DSS limitations, or so called implementation challenges (Hochman and Carberry, 2011).

Of the many findings in this body of work, two key issues have been revealed that question the underlying assumptions of DSS. Firstly, users need to be involved in the tool development process to be effective. Secondly, and in connection to the first, tools are used more as learning than decision support tools.

Emerging consensus

A common failure of early DSS was that they were developed by researchers using their scientific paradigm, and so failed to take adequate account of user and other stakeholders’ perspectives (Cox,1996). The importance of stakeholder involvement has long been noted, Nelson et al. (2002), for example, charts DSS research and development that has facilitated interaction between researcher and farmer back to 1980s (Hearn et al., 1981;Kingwell and Pannell, 1987;Woodruff, 1992). As experience grew the importance of involving stakeholder partnerships to improve relevance of research and analysis to decision-makers emerged as the key common theme in discussions on effective DSS. In line with this a body of work was built up describing the value of participatory DSS development from model- based intervention (Keating and McCown, 2001; Lynch, 2000 Newman, 2002).

One case of particular significance is the development in participatory design of DSS (Carberry *et al.*, 2002) in the farming systems section of CSIRO. The FARMSCAPE programme represented a new paradigm of DSS in that scientists explored, together with farmers and advisers, how simulation could be used as an aid to decisions about grain production inputs in variable climatic situations. This programme was unique in that it used qualitative evaluation and monitoring to reflect on the development process and outcomes, providing detailed longitudinal insights and socio-technical analysis of the approach (McCown *et al.*, 2009).

The development process involving stakeholders enabled an interactive approach which allowed the full extent of the model’s capacity as a learning tool to be realised. This built on observations of the way the DSS were being used to support intuitive thinking or to adjust rule of thumb decisions (Long and Parton, 2012), which was contrary to scientists’ expectations. A consensus grew amongst commentators that DSS have an important use that had been frequently overlooked: that they can be used heuristically, that is, as an instrument of discovery. Thus, DSS were seen to have the capability to act as a computer-aided learning device, rather than solely as a decision-making tool. In particular the use of models for simulation-aided discussion and exploration of alternatives or ‘what ifs?’ revealed their capacity for prompting learning (Keating and McCown, 2001). As reported “researchers were surprised to find that yield forecasting and tactical decision making, anticipated to be analyses that were both site- and season-specific forecasts, had served farmers as ‘‘management gaming’’ simulations to aid formulating action rules for such conditions, thus reducing the need for an on-going decision-aiding service” (McCown et al., 2012, p1)

Walker (2002) notes that “DSS can be designed to account for the fact that farmers prefer to rely on intuition and experience by deploying them as structured learning tools so that the decision process, embedded in the tools, can be learned, adapted and adopted by decision-makers". This is supported by a number of other commentators who agree that DSS should be designed to help users understand how things work (Stone and Hochman, 2004) or to educate farm managers' intuition (McCown et al., 2009). Scientists also saw the DSS as important for planning management strategies for a coming season to critically evaluate the full range of possible outcomes and the probability of achieving those outcomes. As such, as Hochman et al. (2009) noted, scientists aimed to put the analytical power of APSIM into the hands of growers and agronomists to produce simple "what if" scenarios rather than provide deterministic decisions.

Assessing management alternatives in this way facilitates knowledge communication between stakeholders. DSS have been observed to mediate social learning through collaboration and learning amongst stakeholders and with the development team (Jakku and Thorburn, 2010); to play a role in heuristic learning and network building around the land use policy and planning issues (Sterk et al. (2009); and capacity building when used in groups (Krueger et al., 2012; Voinov and Bousquet, 2010).

This view, that DSS were more about learning support than decisions per se, led to a reorientation or definition of DSS as broader initiatives of knowledge transfer. It also led to a realisation that, while most farmers did not routinely use DSS, many have adopted lessons learned from the information and dialogue they generated, and that their use might be more transient, with users stopping using tools once they had "learnt the principles" (Long and Parton, 2012). Understood this way, DSS became more supportive and relevant to the end-users' decision-making process (Hayman and Easdown 2002; Walker 2002), and allowed improved communication and collaborative learning (Allen et al., 2017).

Conceptualising DSS

This period of discussion and reflection has been accompanied by an evolution in thinking conceptually about DSS amongst interested scholars in Australia drawing on different bodies of international work.

Decision making

McCown (2002a,b) emphasised the need to learn from the broader history of DSS and Operation Research (OR)[46] pointing to parallels with the long recognised 'implementation problem' identified 50 years ago in OR (Ackoff and Sasieni, 1968) and from social and management theory. Drawing on this they re-examined the role of DSS in the farmers' decision space "when DSS attempt to tell managers what to do by presenting an optimal solution based on expected value or expected utility rather than help the manager satisfy their needs in a real-world situation which is uncertain, complex and unstructured. DSS should also attempt to support a continuous flow of behaviour towards a set of goals rather than a set of discrete episodes that involve choice dilemmas" (McCown, 2000a)

The challenges of dealing with the epistemological gap between science and practice, and integration of hard and soft approaches is taken up by critics of DSS. They point to the fact that tools are built on erroneous normative assumptions that science driven DSS fill the farm level 'information deficit', and some argue against the use of tools completely describing the proposed use of models in this way as a 'category mistake', that is, it conflates different categories of knowledge, and different ways of knowing (Cox, 1996). Contributions to this theorisation come from practitioners (Nicholson et al., 2015) and those interested in how digital tools fit into farmer wider learning environment (Starasts, 2015).

New ways of thinking

[46] Operational research looks at an organization's operations and uses mathematical or computer models, or other analytical approaches, to find better ways of doing them (Operational Research Society, 2006).

Systems perspectives have informed DSS thinking from early analysis (Macadam et al.,1990). Referring to information systems development, Newman et al. (2002) identified the variance between formal methodologies and the actual subjective needs of developers as a disjuncture between rational and technical approaches of hard systems and the mostly social processes involving multiple perspectives of soft systems approaches.

Farming Systems Research perspectives heralded new ways of thinking about DSS and reoriented the focus towards epistemological and sociological reasons as a way of explaining why model- based interventions were not successful (Keating, 2001; McCown 2001, 2002), The combined experiences of previous projects, and of the Farmscape project in particular, indicated that developing a successful tool from a crop simulation model requires "a collaborative effort between farmers and scientists in which the model is used as a device to assist in organising knowledge of the participants, rather than as a source of knowledge in itself" (McCown, 2009). Thinking this way McCown (2009) claimed to have reinvented the concept of computerised support for farmers' management decisions, and that DSS could be invigorated through transdisciplinary approaches. Also drawing on systems frameworks, Hayman and Easdown (2002) used an ecological framework to explore the technical, social and management constraints on the use of the WHEATMAN tool.

This aligns with Cox's (1996) view point, that we should question the assertion that the primary benefit of this activity was the production of DSSs intended to aid routine decision-making at farm level. In this sense he asserted that the most significant contribution of early attempts at decision support were not the actual production of DSS, but rather the bringing together of researchers and farmers to improve farm management. At the time Power (2003) argued that this shift in ideology and approach of the modelling community could trigger new ways of approaching research and DTS development, indicating that DSS could be responsive to not only technological shifts, but also new ways of thinking.

This in turn inspired other work and commentary on participatory DSS (Jakku and Thorburn, 2010; Eastwood *et al.*, 2012), and has prompted calls for a wider view of decision support to encompass all forms of scientifically-informed decision support that takes away uncertainty; and to understand a decision not as a single event but as part of a whole farm management and adaptive learning. Jakku and Thorburn (2010) developed a conceptual framework for guiding the participatory development of DSS. They saw the model acting as a "boundary object", facilitating a connection between farmers and advisors, extensionists and researchers to co-create knowledge. Their vision of the model applications process was to "facilitate co-learning" rather than "produce answers" providing a "more sophisticated and humble vision of the benefits derived from modelling (Thorburn et al., 2011) compared with the used/not used framing of earlier evaluations" (McCown et al., 2002).

Evaluation and the concept of success

These theoretical developments have led some to question how DSS are evaluated. Cox (1996) for example argued that the appropriate criteria of success lie in the effectiveness of the DSS development process in bringing different points of view to bear on an issue of common concern, not in the need to run process models whenever a routine decision has to be made. Stone and Hochman (2004) using qualitative evidence, provided a more nuanced analysis of success beyond extent of adoption of DSS, and proposed a set of 'success factors' which would require a change in attitude by many DSS developers.

Building on insights from the literature more broadly (outside Australia) scholars have linked evaluating success to overall framing of DSS, their development and the way impact is assessed. For information systems research DeLone and McLean (1992) argued that the ultimate dependent variable is "success" but point out that the concept of success itself has not been adequately defined or explained in the literature. They proposed six major interdependent dimensions of system success: system quality, information quality, use, user satisfaction, individual impact, and organisational impact. These underpin assessment of DSS today, although the DSS literature in agriculture tends to have a particular concern about the former dimensions, focusing on design and performance, but paying less paid attention to the latter two. They argue that, "shopping lists of desirable features or outcomes do not constitute a coherent basis for success measurement" and that more research is needed on individual impact and organisational impact. Other scholars have identified the need to consider the wider settings that decision making operates in, and with respect to this, the absence to data on project planning or evaluation of outcomes (Matthews et al 2011). Allen et al (2017) use an outcomes-based Theory of Change approach in conjunction with DSS development to support, both wider problem-framing and outcomes-based monitoring and evaluation, and show how placing the DSS within a wider context can "contribute" to long- term outcomes. These conceptual insights can enrich our understanding of DSS success by positioning the notions of success in the contemporary evaluation literature (Berriet-Solliec et al., 2014). They also raises the question of how problems are represented and how traditions draw and re draw the boundaries around their systems of interest.

Building a Cumulative tradition

A cumulative tradition, conceptualised in the field of Information Systems, is achieved when researchers build on each other's and their own previous work; definitions, topics and concepts are shared; there is some definition of orthodoxy, while unorthodoxy is not discouraged (Keen, 1980; Eom, 1995). Arguably a cumulative tradition has been emerging as DSS development moves towards a level of maturity on the back of increasingly rigorous empirical work, reflection and theorisation; and as a shared understanding about basic concepts and entities developed amongst a community of DSS developers and researchers. In Australia (and NZ) this has been characterised by reflection processes allowing an emerging consensus on the two phenomena discussed above, evolution in thinking in line with empirical findings and experiences, as well as questioning assumptions including how success might be conceptualised. Despite contested understandings of implementation issues persisting (Hochman and Carberry, 2011), and researchers addressing different aspects of success making comparisons difficult, the body of work suggests that a cumulative tradition has been achieved (Fig 1).

A critical question remains however and that is to what extent have the lessons learned been acted upon? Stone and Hochman (2004) suggest that the factors leading to 'success' or 'failure' of DSS are generic, and that the lessons learned from one or other DSS can be applied when considering developing or deploying another. However they point to "our [researchers] collective inability to have learned from it [the evidence that DSS fail]", and that many scientists continue to develop and attempt to deploy DSS. A review in 2012 for GRDC might support this, finding that over the previous years at least 68 computer-based tools have been developed to support decision-making in the Australian grains industry. It concluded that many tools are still being developed without much evidence of uptake but that some tools have a long life of use and experience [47].

Hochman and Carberry (2011) suggested that lessons had been learned but not necessarily enacted. They set out to determine what lessons can be learned from the literature and from the recent experiences of champions of DSS development and delivery efforts; and then to ascertain whether these lessons are accepted and absorbed by the DSS community of practice in Australia. In a survey of these champions there

[47] In 2011, 21 tools were listed (Climate Kelpie, 2010) available for supporting farmers' management of climate related risks and another six tools for use by researchers concerned with climate risk management in agriculture showing that tool development was still supported and an active part of R&D.

was a lack of unanimous support for any of the propositions they had derived from a literature review and they took this to indicate that, "after more than 30 years of agricultural DSS development, any statement in this domain is still contestable". However in a workshop held with a selection of the same participants they uncovered "encouraging signs that these DSS development efforts have benefited from lessons of past experiences". The champions reached a consensus on the key recommendations for future DSS development. In their conclusions the authors note that achieving these requires the commitment of a critical mass of appropriately skilled people involved in the development of a DSS. A shift in evaluation approaches from assessing DSS functionality and usability towards assessing how DSS facilitate learning, discussions and decision making has also become apparent and is a promising sign (Starasts, 2018).

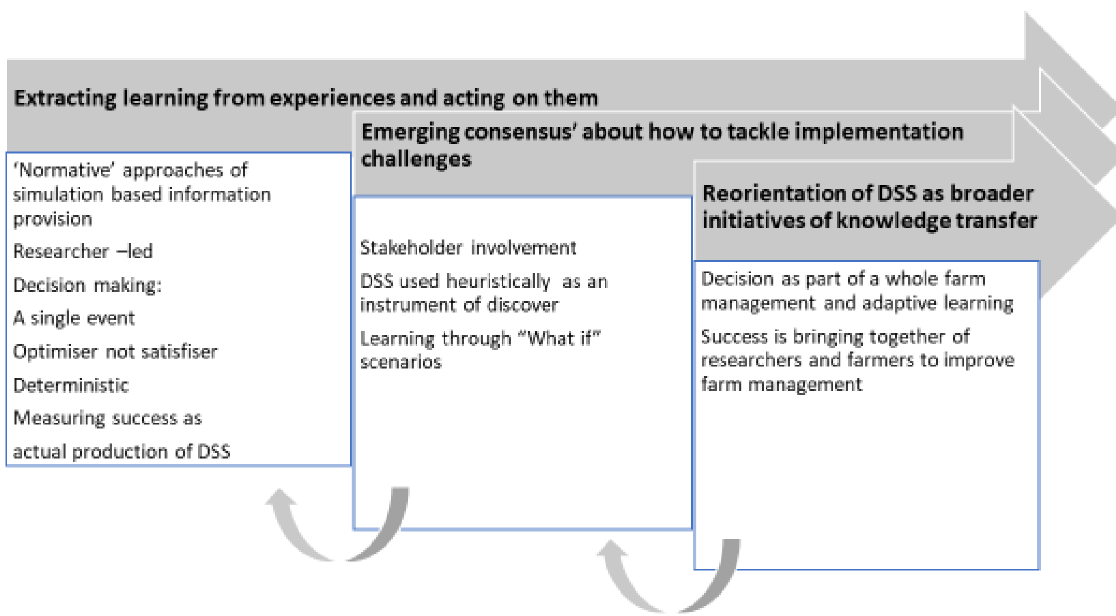

Fig 1 A Cumulative Learning Tradition in DSS

Organisational learning theory can potentially explain the difficulty in enacting lessons learned. Organisational learning is defined as a process of changing organisational actions through new knowledge and understanding, where learning involves mechanisms which link reflection and action. In R&D funding for DSS is often project based. Swan *et al.* (2010) question the value of project work in firms, which often occurs in iterations in an organisation, suggesting that even where there is significant learning generated within projects, there are often difficulties in capturing or translating this learning into new routines and practices at the level of the organisation. Their work suggests that firms generally only learn from projects, via the accumulation of experience amongst groups and individuals where the project context allows. This has some relevance to the research environment and the projectivisation of research projects arguably creating highly heterogeneous forms of learning which cannot always contribute to wider learning in organisations. It also questions to what extent the learning is embodied within the groups and individuals involved or whether it diffuses to organisations as a whole.

One way of capturing or translating learning into new routines and practices is to expand evaluation to include an explicit institutional[48] learning agenda to allow research managers to monitor and evolve new ways of addressing goals. From an Innovations Systems perspective, Hall *et al.* (2003) critiqued impact assessment research and argued that traditional assessment of 'success' needs to recognise systems of reflexive, learning interactions and their location in, and relationship with, their institutional context. Incorporating reflective approaches to assessing success and learning agendas as mechanisms to translate learning into new practices in organisations, could extend the concept of Cumulative Tradition to a Cumulative Learning Tradition.

New knowledge landscape

Australia's agricultural research, development and extension (RD&E) continues to be in a state of transition (Hunt *et al.*, 2014) and in need of reinvigoration, particularly given development in digital technologies (Ampt *et al.*, 2015; Eastwood *et al.*, 2017). Significantly the emergence of digital agriculture and big data heralds a radical change to the way growers are provided with, and access information, and make decisions. The impact of this disruption on the cumulative tradition of DSS in which researchers have built up a body of work, experience and learning deserves attention. While some see it as a threat and a loss of valuable diagnostic learning, other see opportunities for harnessing big data and the analytical powers of models to lead to a virtuous circle allowing a new generation of models and decision support (Capalbo et al., 2017).

Conclusion

We can argue that a cumulative tradition has emerged within the community of DSS developers and researchers. This has been characterised by reflection process allowing an emerging consensus as well as evolution in thinking in line with empirical findings and experiences. Enacting this learning could be enhanced with capturing or translating this learning into new routines and practices at the level of the organisation and extend this concept to a cumulative learning tradition.

[48] Institutions as distinct from organisations are existing sets of norms, rules, routines or shared expectations that govern actors' behaviour that determine how things are done.

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RESIDUAL BIOMASS MANAGEMENT IN AGRICULTURAL SYSTEMS IN THE DRÔME VALLEY. DISCUSSION OF TWO PROGRAMS OF ECOLOGIZATION: INDUSTRIAL AND EARTHBOUND

Andréa Wiktor Gabriel[a], Sophie Madelrieux[b], Philippe Lescoat[c]

[a] Univ. Grenoble Alpes, Irstea, UR LESSEM, France
[b] Univ. Grenoble Alpes, Irstea, UR LESSEM, France
[c] Université Paris Saclay, AgroParisTech, France

1. Introduction

Residual biomasses, revealing the problematic nature of our interdependencies in the ecosystem

Residues are ”materials *that remain after physical or chemical operation, industrial processing, manufacturing, especially after extraction of higher value products.”* (Larousse 2018). In agricultural systems, residual biomass (RB in the rest of the text) or Residual Organic Products refers to *”any organic matter of residual origin (from an agricultural, industrial or urban activity), and spread on agricultural land to recover or recycle the nutrients and organic matter it contains”* (Paillat-Jarousseau et al. 2016). This includes manure, green waste, straw and compost (Leclerc 2001).

The circulation of RB has long nurtured close interdependencies between different systems : between urban and agricultural (Barles et al. 2011), between ecosystems and food systems (Altieri 1999), crops and livestock (Lemaire et al. 2014). Agricultural systems play a pivotal role in this metabolism : they are the site of multiple production practices (crops, livestock,.), use (spreading,.), transformation (composting, methanisation,.) of RB. During the industrial revolutions, the metabolism of RB has undergone radical changes. The discovery in 1909 of the Haber-Bosch process enabled agriculture to break the need for animall dejecta (Gu et al. 2013), forming a ”metabolic rift” (Foster 2000). ”This is a sad hoax, for industrial man no longer eats potatoes made from solar energy, now he eats potatoes partly made of oil” (Odum, quoted by Madison 1997). While they have long been resources, RB have gradually been considered as waste (Monsaingeon 2017).

This new relationship with the ecosystem has proved to be problematic : industrial and urban systems are confronted with waste that they have difficulty evacuating, generating pollution in the environment and impacting ecosystems (eutrophication, potability of water) (Bahers et al. 2019). The increase in the circulation and transformation of biomass involved in agricultural systems, both in terms of distance and volume, contributes to the depletion of resources (Fernandez-Mena et al. 2016). Soil life has declined dramatically in many cultivated soils (Díaz et al. 2006).

These reasons, which are key to the future functioning of agricultural systems, contribute to questioning the management of RB and their *transformation* in particular.

Acting on the metabolism of RB : a problem where science and politics seem inextricably linked

Debates on the management of the RB find an ambivalent place at the crossroads of science and policy. The metabolic rift is at the heart of essential political debates : as early as the 19th century, pollution and health problems have been the subject of petitions, demonstrations and public statements (Monsaingeon 2017. Today, the metabolic rift is the subject of public policies aimed at remedying it in many countries, and is considered one of the existential threats to the future of humanity, and is regularly popularized as such.

The scientific choices for representing metabolism and commitment to action are strongly intertwined (Gabriel et al., forthcoming). Representations of metabolism, as a scientific object, are themselves carrying political implications. The choices of what is represented as acting factors, the scales and functional levels chosen, are not independent of the choice to privilege certain actors (particularly economic) to the detriment of others. For example, representing metabolism in the form of biomass flows between agro-industry players contributes to considering these players as potential partners in action-research programs (Gabriel et al., forthcoming).

There is some scientific controversy about what should be a good metabolism. A variety of schools, each with a certain political agenda, exist : social metabolism, Marxist approaches to the metabolic rift, agroecology, etc. (Gabriel et al., forthcoming).

Research question and article outline

This diversity of programs and representations poses a problem for an agronomist wishing to act on waste biomass in agricultural systems. In the one hand, this poses a problem for the scientific nature of the work carried out : how can we ensure that our research is not just a mere reflection of our political opinions ? On the other hand, how do we position ourselves to act in light of this diversity of political programs, which is reflected among our scientific, institutional or agricultural partners ?

It seems essential to be able to discuss different scientific and political agendas in a concrete situation. We propose to discuss two programs : (1) Industrial ecology as a modernising and engineering program and (2) earthbound, as the ecology of pragmatic sociology. We will seek to see how farmers' RB exchange practices fit into the 2 programs, and to to identify lines of fronts and convergences.

2. Analytical framework

Among the diversity of existing ecologisation pathways, two programs are particularly significant : (1) Industrial ecology as a modernising and engineering program and (2) earthbound, as the ecology of pragmatic sociology.

Industrial ecology, a modernising and engineering program

Industrial ecology (IE) aims to break with a linear view of the economy, which requires the extraction of resources and the treatment of waste. It derives from the analogy between natural and industrial systems : Natural ecosystems are proposed as models for industry (Ayres et al. 2002). "Our industrial system would behave like an ecosystem, where waste from one species would be a resource for another species. The products of one industry [would] be the inputs of another, reducing raw material use and pollution" (Frosch et al. 1989).

The main object of study in industrial ecology is industrial metabolism, defined as **"human mediated matter change for sustaining a productive system's economic activity"** (Wassenaar 2015). It is analysed using two complementary concepts : funds and flows. This distinction is borrowed from Georgescu Roegen, who uses it in the study of economic processes (1971). A *flow* represents the change in the system : it is generally used to represent an input or output of a given process. The *funds* are durable entities, which are the "active agents of the process", while the flows are "used by the agents, or acted upon by the agents".

The purpose of these approaches is to "**close the loop**". The paradigmatic vision of sustainable industrial systems is characterized by minimized physical exchanges with the "natural" ecosystem (Wassenaar 2015), as well as sustained exchanges between different industries, operating in a symbiotic way (Ehrenfeld et al. 1997). Waste from one forms the inputs to the other, the aim being to balance production and use through material exchanges. This program has been supported by public authorities and industries since the 19th century, and is part of the program to "modernise" the productive system (Fressoz 2016). Economic agents as well as public authorities are given a central role, as they are considered to be the main bearers of technological innovations (Ayres et al. 2002).

In agricultural systems, this raises the questions of the use of RB in soil fertilisation and their origin (on the farm or otherwise), and/or their substitution by commercial fertilisers. The **carbon (C) and nitrogen (N) content** of biomass distinguishes different behaviours in its interaction with the soil. Biomasses with low C/N behave in the soil like fertilisers, playing a role in fertilising the crop of the year. In contrast, biomasses with high C/N behave like soil improvers, participating in the soil structure, releasing nitrogen over the long term. (Mustin 1987 ; Leclerc 2001). A regularly quoted limit is at a C/N ratio of 25. Below this ratio, nitrogen is in excess and will be released when plants are available. Above this ratio, nitrogen will be taken from the soil solution to meet the needs of microorganisms" (Peyraud et al. 2012). The carbon and nitrogen cycles are not independent : their coupling is considered virtuous from an ecological point of view (e.g. interaction between crops and livestock in a traditional farm) (Lemaire et al. 2014 ; Soussana et al. 2014). This model is extended to exchanges between farms (Moraine et al. 2017) and more generally at the territorial level.

2.2 Earthbound, the ecology of pragmatic sociology

In agro-food studies, pragmatic sociology brings together influential approaches that have challenged previous understandings and frameworks (Kristensen et al. 2016). It focuses attention on hybridity and the role of heterogeneous associations in complex networks (Goodman 2001).

The actor-networks theory (ANT) seeks to understand what is happening in the process of building and stabilizing networks. Both humans and non-humans participate in the action (Callon 1990). Representations describe actor-networks: a composite consisting of heterogeneous elements including humans, materials and technical devices that flexibly adjust to one another and act collectively (Çalışkan et al. 2010). The actors' discourse are "taken seriously": the researcher does not seek to reveal the hidden attentions of the actors by applying an analytical framework external to the situation he describes: he limits himself to describing the entities, themes, objects that the actors use to justify their practices (Darré et al. 2007).

Applied to biophysical or ecological interactions, the pragmatic approach **describes the diverse and multidimensional interdependencies that link all "earthbound" entities.** The goal of pragmatic sociology is not normative, but procedural : it intends to bring attention to the network of ties that binds all terrestrial life forms. These "earthbound" attachments forms the basis for a new definition of ecology (Latour et al. 2017). It seeks to pay attention to the links of interdependence between humans and non-humans and to open the door of politics to all living things in a process of hybridization. (Latour 2015 ; Conway 2016). This program is led by philosophers and sociologists, ecologists, environmental associations, but also agronomists (Barbier et al. 2013; Cohen 2017). "Earthbound"s are those who assume a belonging to the Earth in the diversity of the worlds experienced by its different beings.

World	Value	Test	Qualified objects and subjects
industrial	efficiency	competence	Technical infrastructure ; method ; plan ; Engineer ; professional ; expert
market	price	competition	market goods ; customer ; consumer ; vendors ; merchant
civic	equity	democracy	rules ; citizen ; union
domestic	tradition	reliability	local heritage ; legacy ;family ; authority

inspired	creation	passion	emotions ; body ; creative beings
opinion	reputation	popularity	signs ; media ; celebrity
green	life	sustainability	ecological ecosystems ; living beings ; natural habitats

Table 1 – Worlds according to Boltanski et al.

We wish to apprehend the **diversity of these lived worlds**, while being able to give a synthetic representation of them. One of the analytical frameworks for distinguishing this diversity of worlds is the economy of worth. (Boltanski et al. 2008). According to its authors, objects, subjects are divided into different "worlds", which are coherent discourse regimes in terms of reference values, and in which some entities, subjects, and objects are qualified, while others are rejected. This qualification rely on commonly accepted "tests".

Within the framework of the current Western society, which interests us, the diversity of these worlds is not infinite. The authors have identified 7 of them : industrial, civic, domestic, opinion, merchant, inspired and green (the green world, not present in the initial proposal, is a development proposed by other authors) (Latour 1995)). When they are brought to justify themselves, people always fit into one of these worlds. Thanks to these systems of shared equivalences, which allow each person to find the reference points that will guide his relationships in the situation, relationships between people can be established. For example, the industrial world values optimization and efficiency. Entities such as technicians and professionals are qualified in this world. The value of the entities is tested by model tests such as scientic analysis, accounting, quantification. The table 1 presents the main characterictics of each world.

2.3 The metabolic networks

In order to put into dialogue the analyses under each of the two programs, we propose to use a boundary-object, the metabolic networks (GABRIEL et al., to be published). This approach consists of being part of the paradigm of socio-ecological metabolism (SEM), while allowing multiple visions of what is a good metabolism, to be taken into account. It translates into theoretical and practical considerations, such as: relying on **a relational ontology**; propose **multiple representations**; describe **multiple entities** as agents; value **procedural rather than normative goals** and making room for collective deliberation.

3. Materials and methods

Extensive **surveys** were conducted among farmers. They focused on their RB management practices. The semi-directive framework of the interviews was designed to elicit the description and justification of the RB management practices. 32 surveys were carried out, in the form of semi-directive interviews, lasting 2.5 hours on average. In addition, 20 additional interviews were conducted, bringing the number of surveys describing exchange practices to 52. A collective composting project, was followed up, in particular through non-participant observation of meetings and assemblies. It gave rise to a privileged view of debates and controversies.

The survey was conducted in **the Drôme Valley in France**, an area known for the diversity of agricultural production systems (standard, organic, biodynamic). (Bui et al. 2015), the diversity of local actors involved in agricultural issues and divergent world views. (Sencébé 2001). This is one of the two sites of the BOAT (Organic Agricultural Biomasses in Territories) project, financed by ADEME (French Environment & Energy Management Agency).

3.1 Qualification of RB flows

For each individual surveyed, we qualified the RB flows involved in three categories of practices : (1) Production, (2) exchange and (3) transformation. In each category, we have characterized : the nature of the RB, the flows in and out per year expressed in tons of material and the origins or sources of the biomasses (e.g. neighbour, supplier, animals). RB are characterized according to their carbon and nitrogen concentrations. When information are not available, reference tables are used (Leclerc 2001). RB are divided into three categories : (1) those with a C/N ratio above 25 (e.g. plant residues), (2) those with a C/N ratio below 25 (droppings, manure) as well as (3) commercial fertilisers (industrial processed products, with C/N ratios regularly below 3, regularly produced from processed animal proteins.

Typological keys to distinguish farmers according to their degree of circularity are : (1) exchange of RB with C/N < 25 ; (2) exchange of RB with C/N≥ 25; (3) dependence on fertilizers for fertilization. Exchange takes 4 modalities : import/export/import-export/no trade.

$I_1 = Flow(RB\frac{C}{N} \leq 25) \qquad I_2 = Flow(RB\frac{C}{N} \geq 25)$

Fertilizer dependence in fertilization is described by I3 . It relates to the degree to which farmers substitute commercial fertilizers for RB. One way to measure it is to compare the units of nitrogen provided by RB with those provided by external fertilisers (minerals, such as ammonium nitrate, organo-minerals, commercial organic fertilisers).

$$I_3 = \frac{NitrogenUnits^{commercial\ fertilizers}}{NitrogenUnits^{total}}$$

Farmers can be divided into three categories : those who are strongly ($I \geq 66\%$), moderatly ($66\% \; I \; 33\%$) and lowly ($I \leq 33\%$) dependant on commercial fertilizers.

3.2 Qualitative description of practices

We paid attention to the discourse of the actors, as they were led to justify their practices. By following a pragmatic approach, the discourses are ”taken seriously” : this means we do not seek to reveal the hidden interests of the actors. On the contrary, we consider that justification is in itself meaningful. (Darré et al. 2007). The farmers' speech was coded using RQDA.

We analyzed the **justifications**, describing the situations in which farmers are led to question their RB management practices. For each type of practice, an attempt was made to identify what constitutes good metabolism from the farmers' perspective. (1) What is a good flow, a good waste biomass ? (2) What are the active and durable entities, the funds, that contribute to good metabolic functioning ? We have tried to describe the objects, the subjects, the criteria mentioned by the farmers, as well as the way in which they recompose themselves among themselves and come into conflict with each other. (3) Finally, we show that each of these representations of a good metabolism is linked to values, within different ”worlds”, relying for this on Boltanski and Thévenot (2008), describing the characteristics, subjects, valued objects and tests specific to each world.

3.3 Data integration : metabolic networks

The data are integrated in a relational database (Access). Both quantitative and qualitative data have been processed in terms of funds/flows and translated into tables of nodes and links. Data is aggregated and processed using SQL requests, generating tables of nodes and links. Representations are then generated using Gephi software.

4. Results

Industrial Ecology

In our study area, high C/N waste biomass has the highest tonnages. These include green waste, industrial wastes such asfruit processing residues, wine making spent grains, fruit compotes, avender straws and distillation residues. Among the RB with low C/N, poultry droppings are particularly represented. The second source of these biomasses is goat manure. These productions are far from reflecting the needs of the territory's farmers. With 21 % of the land is devoted to organic farming, the territory's need for organic matter is much greater than its production.

Six farmers' profile are proposed in table 2.

N	Type	C/N inf 25	C/N sup 25	Dependancy on fertilizers	N (number of farms)
1	Substituent	-	-	High	8
2	Independant	No exchange	No exchange	Low to moderate	16
3	N producer-exchanger	Export	-	Low to moderate	5
4	C producer-exchanger	-	Export	Low to moderate	5
5	Hub	Import and export	Import and export	Low to moderate	7
6	Net C and N importer			Import Import Low to moderate	10

Table 2 – Types of farmers

Substituent farmers include conventional farms that do not mobilize waste biomass. Theirproductionsystemis basedonsubstitutionbyanothersourceofnitrogThiscategory includes large cereal farms, which rely exclusively on chemical fertilizers. Some organic farms also fall within this framework : they include farmers who have decided to completely separate the issue of carbon and nitrogen management in their production system. Carbon is managed through high C/N ratio RB, such as green waste or straw, as well as conservation practices such as limited tillage or long rotations. Nitrogen is applied exclusively with commercial fertilizers. Substituent farmers maintain privileged relations with cooperatives and traders, as regards their supplies of nitrogen fertilizers. As for carbon-rich biomass, it comes from local authorities (green waste dumps) and industries (lavender distilleries, wine cellars). The fact that these farms do not use waste biomass does not mean that they do not produce it : some poultry farms prefer to export all their droppings, without mobilising them themselves, to simplify the technical itinerary or due to a lack of equipment.

- **Independent** farmers do not import RB for fertilizer use, and are low or medium dependent on commercial fertilizers. They are small or medium-sized mixed crop-livestock farms, often in organic farming. Some farms specializing in crops with low nitrogen demand, such as trees or vines, also fall into this category. Independant farmers are not completely self-sufficient : they import commercial fertilizers through cooperatives and traders. In reality, completely self-sufficient farmers are almost non-existent : almost all of them have to obtain fertilizer from outside, even marginally.

N-producer-exchanger farmers export low C/N ratio RB. They are typically breeders (goats, laying hens), who use and export surplus manure. They actively participate in the circulation of C and N flows : they are moderately dependent on commercial fertilizers. They potentially import RB with high C/N, especially straw for their farms.

C-producer-exchanger farmers import nitrogen, which takes the form of organic matter, for fertilization. The carbon exported concerns cereal straw, sold in bales or exported as standing crops. These are mainly small cash-crops farms, either organic or in organic conversion.

Hub farmers import and export at least one type of biomass. They group together breeders (cattle, goats), export their manure, and complete this activity by managing the manure of other farmers. This category also includes farmers who trade straw. Exchange of RB is greater than farmers' needs : they all maintain a low or medium dependence on commercial fertilizers.

Net C and N importer farmers are dependent on waste biomass for nitrogen fertilisation and soil amendments. They import both nitrogen-rich biomasses (manure, compost) and highly carbonated biomasses (green waste, etc.). The majority of them are farms, regularly engaged in organic farming, without animal husbandry, and which maintain the fertility of their soil through the input of multiple residual biomasses : for example, small market garden farms. They maintain relations with a wide variety of actors : farmers from outside the territory, directly, or by using a transporter. They prefer to use traders rather than the supply cooperative.

Figure 1 provides a representation of **interdependancies between agents**, with the flows of RB between economic actors, distinguishing between the 6 types of farmers.

Importers of C and N C and N producer-exchange farmers are interdependent with each other in exchanges within the agricultural world. These exchanges between these two types of farmers are, for example,"straw-manure exchanges", and are more generally part of the interaction between crop and livestock farming at the territorial level (Moraine et al. 2017). They are nevertheless marginal compared to other types of exchanges. In particular, some hub farmers organize around them heterogeneous networks of farmers. Their exchanges extend beyond the agricultural world : they are regularly in contact with local communities and industries, importing waste and residues.

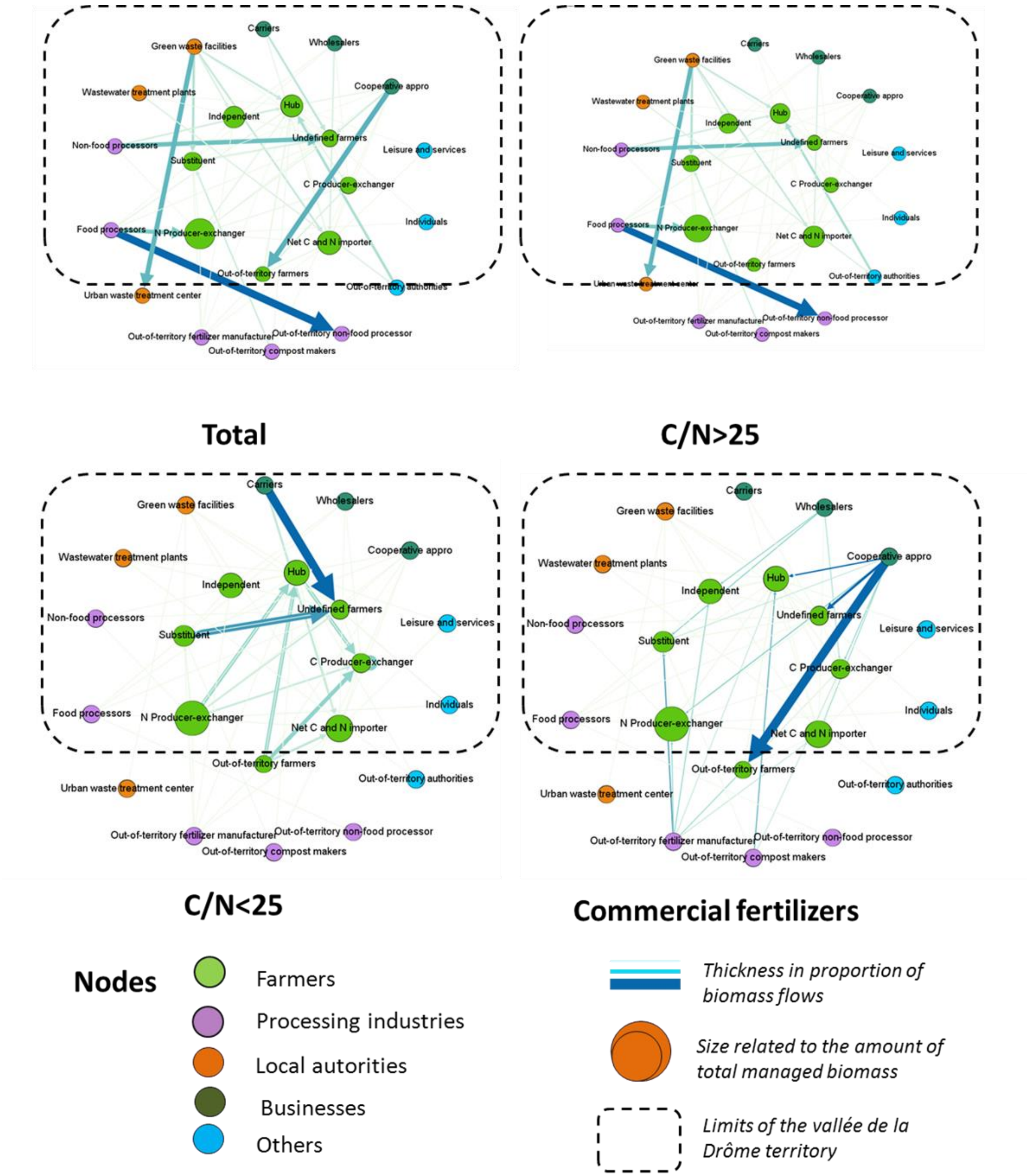


Figure 1 – Representations of metabolic networks between economic actors.

4.2 Earthbound

Among the situations in which farmers are led to question the management of the RB, the situation most often cited is the **closure of livestock farms**. This force other agents (i.e crop farmers) who were dependant on these livestocks farms for their manure to reduce fertilization or to replace certain productions by crops that require less nitrogen. Not all situations are troublesome : **opportunities** also play a key role. Since RB are rare and sought-after, farmers are easily inclined to accept RB whenever an opportunity arises.

What is a good RB for a farmer ? These events lead to a rethinking of relationships, and cause farmers to question themselves what a good RB means to them. The most widely shared criteria are technical : search for ”nitrogen at the best price”, for an ”efficient” product. They are often opposed to other criteria : the local character of the biomass is several times associated with a notion of quality ; the organic label ”without antibiotics”, the ”non-industrial” character, sensitive criteria such as odour and texture are also mentioned.

When a problem arises, such as repeated poor harvests, some farmers seek to test the RB on their criteria of interest. For example, a farmer decides to carry out an analysis of manure, which reveals that the nitrogen concentration is ”3 points lower than what was announced”, or when looking at green waste, he discovers ”lots of small pieces of plastic”, and calls on the community to carry out more regular physico-chemical tests.

Trade-offs between these criteria regularly occur, for example, a farmer is looking for both a reasonably priced supply of nitrogen and local resources. These tensions between different forms of values are regularly solved by the actors themselves. For example, one farmer used to obtain manure from his neighbour. The disappearance of his manure supplier led him to rethink his demands, expressed as ”supply at a reasonable price”, and ”mobilization of the territory’s resources”. Unable to find new local resources under these conditions, this farmer ended up finding a compromise, changing the scale he considered ”local” : ”Today, it no longer makes sense to think on a small scale, to exchange neighbours. ”Today, the scale is the region.” ”It’s true, we would like it to be less than 50 km away, but well, we can’t find any.

In other cases, the compromise between these different criteria is not found. For example, a farmer finds himself torn between his search for nitrogen and his refusal to accept any risk of salmonella contamination. He says he is very concerned about the sanitary measures that accompany the discovery of salmonellosis on farms, which makes him reluctant to enter into exchanges with another potentially affected farmer, even if it means missing what he considers to be an agronomically attractive opportunity : ”[a colleague contaminated with salmonellosis] had called me to collect his droppings. I thought about it...then I didn’t take it, I don’t want it on my farm...when you get [salmonellosis] on your farm, it’s like being in hell”.

Recompositions and oppositions of the actors-networks What represents a ”good RB” or good flow is dynamic. Changes in flows imply a recomposition of collectives of human and non-human actors. In some cases, these recompositions are marginal : Not all farmers are affected in the same way by these problematic situations. Faced with the closure of a partner farm, a farmer succeeds in entering into other contracts: a compromise is reached, and with some reorganisation, RB management practices continue.

In other cases, the changes are more profound, and strongly recompose the actor-networks: for example, the disruption in manure supply led one farmer to limit his area under organic conversion, then his sells, his choice of crops, etc. These situations of tension regularly give rise to conflicts. For example, a group of farmers decided to oppose the cooperative, which only offered Spanish compost, and stopped supplying French compost from a supplier whose quality was unanimously recognised by the farmers. This supplier is characterised as ”poor” by a Diois polycultivator. Discovering that he was not alone in this case, in discussion with colleagues, he joined a collective of dissatisfied farmers, taking the initiative to write to the cooperative, urging it to reintroduce French compost.

These conflict situations sometimes lead to the expression of direct criticism from certain actors: the difficulty in finding manure, while in most cases it is attributed to a general decline in livestock farming, is denounced by one farmer as the result of unjustified privileges : ”X. [a neighbour] finds manure easily, he is elected to the chamber [of agriculture], so as soon as a new livetsock farm shows up, he is the first to be there [and get the manure]. [...] We are nothing [to them]. We just watch”.

These justifications and controversies help to describe what a good metabolism is, from the farmers’ point of view. By relating the objects and subjects qualified in the framework of the Economy of Worth, we are able to identify what a good metabolism means in each of the worlds. Table 3 presents for each world what is considered a good practice, and how it translates into flows and funds.

World	Value	Flow (What is a good biomass?)	Fund (What is considered as valuable and active?)
industrial	efficiency; optimization	Fully valued by the plant/ without losses	Soil analyses; quantified figures; concentration of substances; NPK; mineralization rate.
market	competition; rivalry	Provides nitrogen/nutrients at the best price;	a diversity of suppliers; diversity of products; sales people; internet shopping
civic	democracy; community	Provides services to multiple local actors	the local community; meetings; grants; collective projects
domestic	tradition; hierarchy	Valued according to traditions and habits	family; inheritance; friends
inspired	creation;intuition	Gives the opportunity to follow one's inspiration or feeling	esoteric references; biodynamics; personal experience and feeling
opinion	reputation	Renowned for its quality	the opinion of neighbours; informal discussions
green	living beings interdependancy	Supports natural processes	soil life; ecosystem services

Table 3: Definition of a good metabolism in each world

4.3 Discussion of the 2 programs through metabolic networks

We propose to discuss earthbound and industrial ecology, based on a theoretical application of metabolic networks (network ontology, common grammar) (1), the other based on its practical conditions of implementation (debating irreducible representations, multiple actors, democracy and deliberation, (2).

Theoretical discussion: Farmers are part of many worlds : industrial ecology is only one of them.

Figure 2 shows the main funds mobilized in the management of RB for each type of farmer. Table 4 summarizes the share of each world in the justifications, by type of farmer. The industrial world is unquestionably the most mobilized by farmers in justifying their practices. They all refer to it, regardless of the group they belong to. Nevertheless, the place occupied by the industrial world is not uniform. By quantifying the share that the entities of each world represent, we can get an idea of the importance of each world in farmers' practices.

The farmers who contribute the most to the looping of flows (independants) attach the greatest importance to it : the industrial world dominates, and represents 81 % of the justifications. On the other hand, the least circular farmers (Net C and N importers, Substituents) include less than 50% of their justifications in the industrial world.

Type of farmer	Industrial	Market	Civic	Domestic	Opinion	Inspired	Green
Substituent	48	17	29	2	2		
N Producer-exchanger	81	6					9
Hub	51	17	20	3		1	
Net C and N importer	49	3	8			21	17
C Producer-exchanger	62	8	20	4	4		
Independant	81	1		6			17

Table 4

justifications by worlds, and by type of farmers

Practical application: a collective compost plant project

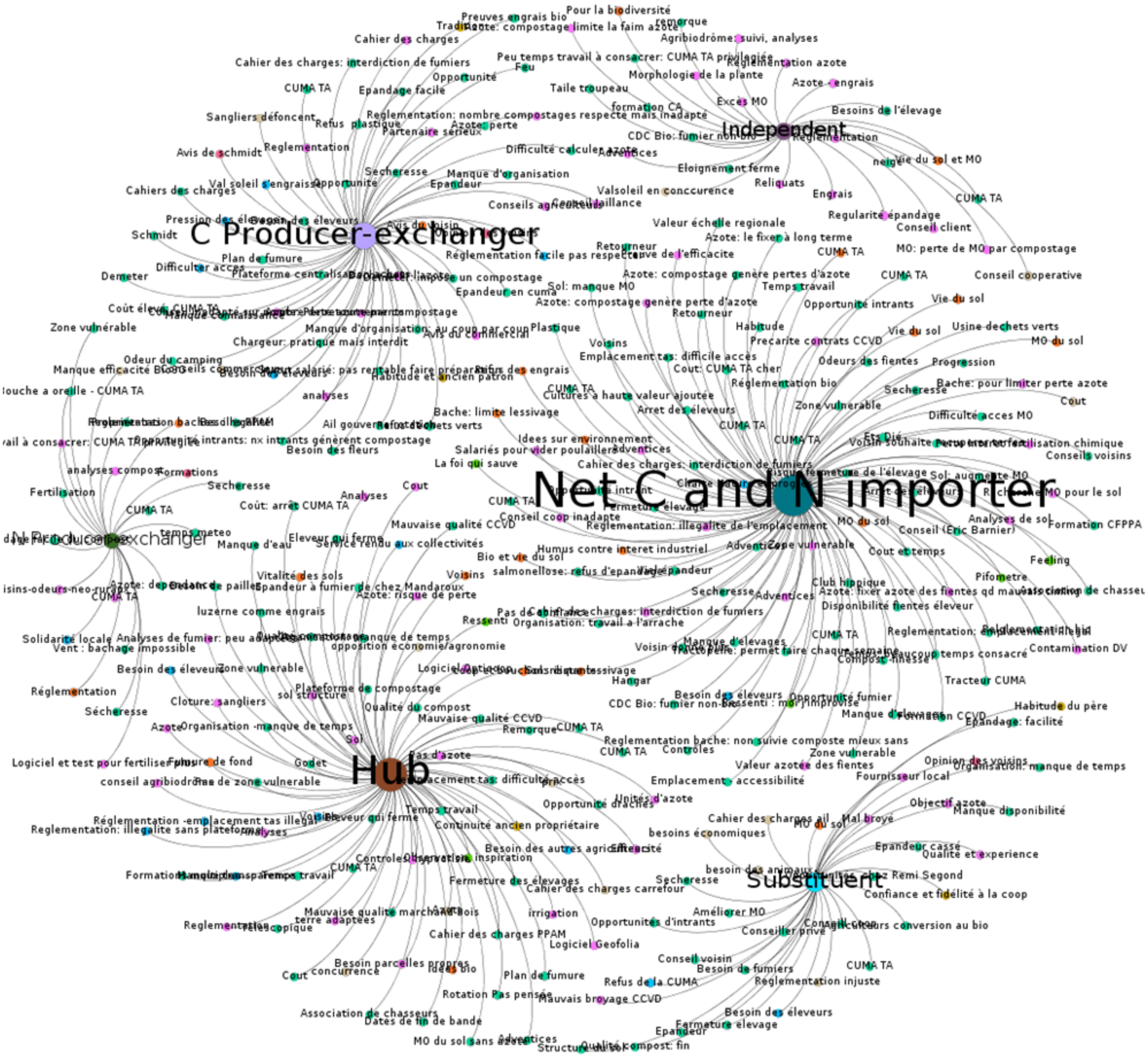
The association has its origins in the discovery of a shared interest in biomass by a cooperative of poultry farmers and a local authority. A compost plant was seen as a way for poultry farmers to find an easy outlet for their droppings, and for local authorities to guarantee local recovery of their green waste. An association was formed. The potential seems great, especially since many industries currently export waste far from the territory. The diversity of the biomasses lead the association to call upon a consultant to identify available resources and to propose technical solutions for discussion.

The study proposes an inventory of potential inputs and outputs. It confirms the importance of poultry droppings, which represent more than 50 % of the total 4800 tons of potential agricultural effluents. Concerning industrial waste, only a tiny part (2700 tons) is available for the project : many companies are bound by contracts, preventing them from freely redirecting their waste to the composter. Concening outputs, or market opportunities, the data is highly indeterminate : only the areas of organic land for each crop are known, but the willingness to pay is unknown. The regulatory risks, linked to the existence of different product qualities, are also highlighted.

Different technical options are proposed : one or several composting sites ; production of bulk or granulated fertilizers; treatment of salmonella-infected manure; integration of sludge from wastewater treatment plants ? The debates bring out a point of agreement on the centrality of profitability : the project must be economically viable, and the final product must be competitive. Two scenarios emerge : a single platform, on a single site, with a storage building and granulation. The second scenario integrates sludge from wastewater treatment plants, but maintain two separate sub-plants, one of these being kept sludge-free.

The technical arbitrations are debated by an extended panel of farmers. Workshops are organized for three different themes : the choice of options, the cost of treatment (for local authorities and industries), as well as the final cost of the product. These discussions lead farmers to question their own RB management practices, and to describe what a good collective composter would be for them. Some farmers argue that today, they have access to a diversity of biomasses (manure, droppings, green waste), each one being adapted to a specific use. The disappearance of these diverse biomasses and their replacement by a single, standardized product is seen as a risk factor for their own production. Moreover, some biomasses are integrated into informal exchanges between farmers, which involve exchanges of labour or services.

The project of industrial symbiosis is progressively amended, taking into account the multiple attachments of the actors. It appears from the discussions that the expectations of the farmers go beyond the initial logic (economic viability with a competitive product). The study of the multiple technical constraints reveals that the product is unlikely to be the cheapest on the market, nor the most efficient in terms of nitrogen. The fact that despite this, the various stakeholders have taken the decision to continue reveals the importance of these multiple other attachments. The moderators of the debates summarized it under the term 'offer of service' : the goal of the compost plant is to provide services to farmers. For example, to help the poultry farmers with the management of salmonellosis, while ensuring their participation.



	Worlds	Values	Example of funds
	Industrial	Efficiency, optimisation	Scientific analysis, a technician
	Civic	Democracy, community	Local authorities, associations
	Domestic	Tradition, hierarchy	Family, olders knowledge
	Inspired	Creation, intuition	Emotions, personal inspiration
	Market	Competition, rivalry	Businessmen, marketable goods
	Opinion	Reputation	Others people opinion
	Green	Human non-human interdependancy	Natural environment, living entities
	Unrelated		

Figure 2 – Representations of the actor-networks made up of the funds mentioned in the justifications, by type of farmer

5. Discussion

Frontlines and meeting points between the two ecologies

The two programs, although theoretically far apart, have many points in common in the concrete situation of waste biomass management in the Drôme valley. The foundations of industrial ecology are already widely taken into account by farmers, and they demonstrate a strong attachment to the values (efficiency, optimisation) and objects of the industrial world, as well as to the same attributes of the biomasses (carbon and nitrogen content), and the same qualification of the actors (technicians, analyses) in the choice of their practices.

Nevertheless, the study of farmers' attachments reveals broader attachments that go beyond the industrial world (domestic, inspired, etc.). These attachments may prove to be compatible, even synergistic, with the objective of closing the flow loop. In other cases, these attachments may come under tension : circularization results in the breakdown of certain attachments, i.e. a break in interdependence between cereal farmers and livestock farmers.

These meeting points and fronts contribute to questioning what a "good" metabolism is, as far as the management of residual biomasses is concerned. They ask us about the ends : do we want to loop the flows at any cost, even if it means destroying other forms of attachment? On the contrary, do we want to valorise other forms of attachment, even if it means helping to maintain sub-optimal systems? But also on the means : couldn't the looping of flows be based on attachments other than those specific to the industry, by relying on the diversity of the actors' attachments ?

5.2 Perspectives for action

The path we are proposing to think about ends and means together. Metabolic networks can help us in this task. The adoption of a common network ontology, as well as a common grammar, makes it possible to place industrial ecology among the multiple earthbound attachments of farmers. The industrial world provides a very good framework for industrial ecology : the criteria specific to industrial ecology are completely in line with its grammar (Plumecocq et al. 2018). This puts us in the position of being able to discuss different visions of what a good metabolism is, rather than imposing a normative vision.

In the composting project, this was translated into participatory workshops, giving each member the opportunity to express what was important to them. The objectives were defined collectively : the farmers took part in defining what they expected from the composter, and thus in the choice of the technical and organizational system. This requires to accept multiple mutually irreducible representations, and to renegotiate what are considered to be relevant attributes for qualifying biomass flows, or qualified funds.

The main difficulty lies in opening the discussion to the widest possible range of actors, especially those who do not have a direct interest in the project. The "network-metabolic" crossovers also make it possible to highlight anything that is not taken care of in a given collective. For example, the question of the interdependence between the issue of tourism and that of composting.

Limits and weaknesses

However, this study shows strong limitations to this method. Each of the frameworks is not developed in all its complexity, which may contribute to caricature. Iin industrial ecology, networks were represented with incomplete information : not all farmers in the territory were surveyed. This gives an important limitation to the interpretation of the graphs, which should be seen mainly as representative of a certain diversity, and not of exhaustiveness. With regard to earthbound : the framework of the study did not allow the full development of a pragmatic approach, which presupposes a detailed description of all the processes involved. More broadly, following our methodology means adding a layer of complexity to the approach to metabolism, and seeking to describe several mutually irreducible facets of it. Whether in theory or in practice, it therefore implies time, and thus a questioning of the imperative of efficiency specific to many engineering projects.

6. Conclusion

This study proposes to gain a level of reflexivity on the management of RB in agricultural systems. By adopting a certain common grammar, made up of backgrounds, flows, nodes and links, it enables a dialogue to take place between academic traditions that are sometimes quite distant. It raises questions about our own position as researchers. Putting oneself in a position to act, to develop certain attachments (to ecosystems, flow closures, territories, etc.) necessarily involves questioning other attachments (traditions, institutions, etc.). These values are incommensurable (Giampietro 2005), and the diversity of attachments (as rich as human experience is) can only be described in an extremely partial and incomplete way by an investigator. Thus, it would seem that, like our respondents, we are not exempt, as researchers, from questioning our own attachments. Wouldn't that be ecologization: questioning oneself about one's own attachments, and therefore assuming to take a political stand accordingly.

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THEME 3 – AGROECOLOGY AS A RESPONSE TO CLIMATE CHANGE

Agriculture faces many different challenges and has partly lost its connections with nature and with society. This led to several undesired and mostly unforeseen negative consequences. The search for more sustainable pathways for agriculture development has shifted the focus of attention from individual practices at field level towards the farm dimension, farm organisation (ex. in terms of autonomy), farm landscape cooperation (ex. in terms of biodiversity), and even food issues. In all cases, reconnections or new connections between agriculture and its environment (weather nature or society) must be redesigned and created.

iPES FOOD confirms: "What is required is a fundamentally different model of agriculture based on diversifying farms and farming landscapes, replacing chemical inputs, optimizing biodiversity and stimulating interactions between different species, as part of holistic strategies to build long-term fertility, healthy agro-ecosystems and secure livelihoods, i.e. 'diversified agroecological systems'."

CHARACTERIZATION OF DAIRY CATTLE HERD MANAGEMENT WHILE TRANSITIONING FROM PUREBRED BREEDING TO ROTATIONAL CROSSBREEDING.

Julien Quénon[a], Stéphane Ingrand[b], Marie-Angélina Magne[c]

[a] UMR AGIR, Université de Toulouse, INRA-INPT-ENSAT-EI PURPAN, France.
[b] Université Clermont Auvergne, AgroParis Tech, INRA, Irstea, VetAgro Sup, France.
[c] UMR AGIR, Université de Toulouse, ENSFEA, INRA, INPT, INP- EI Purpan, France.

Abstract: Using animal agrobiodiversity is considered as a promising lever to improve farm performances and its resilience. Some dairy cattle farmers adopt rotational crossbreeding to use genetic variability, heterosis and complementarities in dairy breed features. Although it has been increasing since 2010, dairy crossbreeding remains still rare in France, while it is quite common in USA and Ireland... Many studies deal with the performances of crossbred cows compared to purebred ones, for a wide range of schemes and performance criteria. However, little is known about how dairy farmers manage crossbreeding, particularly during the transition of the herd towards crossbreeding. Our study aims at characterizing dairy farmers herd management while they move from pure- bred breeding to rotational crossbreeding. We focused on the evolution of herd configuration management: crossbreeding, mating, turnover and culling practices. We interviewed 26 dairy farmers who have been using rotational crossbreeding for a long time and had at least 33% of their herds composed of crossbreds of second generation in 2018. Data were encoded to build 11 variables describing the evolution of farmer's practices for the period of transition, then processed by a multiple correspondence analysis and hierarchical clustering. Three transition pathways of herd management towards dairy crossbreeding were identified and structured along two main axes. The first axis differentiates farmers according to the rythm of crossbreeding implementation and the depth of change in herd configuration management practices in relation with the role of crossbreeding in the whole-farm dynamics: adopting a predefined crossbreeding scheme on a high number of inseminations in the herd to correct a fertility defect in cows without deteriorating milk performance vs. looking for a customized crossbreeding scheme to create a cow best suited to livestock system changes, even if it means reducing milk performance. The second axis differentiates farmers according to the evolution of herd's turnover practices in response to the effects of crossbreeding on cows' performances: regulating the overflow of crossbred heifers linked to the improvement of crossbred cow's fertility by switching from heifer purchases to sales and increasing industrial crossbreeding vs. increasing dairy crossbreeding insemination because it has only be used on a part of the herd or the rate at which it was set up has been slower. Our findings can be used to support dairy farmers' decision-making to move from purebred to crossbred herds. It also need to be matched by a characterization of herd performances while transitioning towards crossbreeding.

DYNAMICS OF AGRICULTURAL SYSTEMS FACING DISTURBANCES: DOES INTENSIFICATION LEVEL EXPLAIN RESILIENCE?

Dardonville M. [a,b], Bockstaller C. [c], Therond O. [d]

[a] LAE, Université de Lorraine, INRA, Colmar, France.
[b] Agrosolutions, France.
[c] LAE, Université de Lorraine, INRA, Colmar, France.
[d] LAE, Université de Lorraine, INRA, Colmar, France.

Abstract

Identifying the characteristics and properties that influence dynamics of agricultural systems - resilience, vulnerability and robustness - when disturbances occur remains a scientific challenge. More specifically, intensification has a major influence on yield levels, but its effect on yield dynamics is still under discussion, especially in the debate on conventional vs. organic agricultural models. We present results of a systematic review of peer-reviewed studies that quantitatively assessed dynamics of agricultural systems in terms of vulnerability, resilience, and robustness (VRR). We queried the Web of Science and systematically sorted the co-occurrence of terms with VOSviewer to exclude articles outside the intended scope (2 reviewers). We identified 11 articles that evaluated effects of intensification in temperate zones and at different organizational levels: field, farm and region. We analyzed the results of each study through detailed characterization: VRR to what (disturbance), VRR when and where (spatial and temporal extent and resolution), VRR of what (studied system), VRR of which attribute (performance to maintain) and VRR due to which endogenous or exogenous properties (explanatory factors). We summarized results by disturbance, type of production, organizational level and performance attribute. Studies varied greatly in type of production (crops, livestock, vineyards, grasslands) and performance attribute (yield, economic efficiency). We show that crop intensification (intensification of practices and socio-economic characteristics) is not effective at mitigating negative effects of climate change on the dynamics of yield. In the short and medium term, the appropriateness of the production situation (crop, management, soil, climate) and resource availability and dynamics is crucial for designing resilient agricultural systems. In the long term, natural capital must be conserved to ensure agricultural production. We also believe that dynamics must be compared at the same level of production and intensification of practices. Finally, we identify that low intensification levels may result in desired dynamics of yield, and thus resilience, by compromising on high yields to address resource depletion and the degradation of natural capital.

Introduction

To control factors that limit and decrease agricultural production, modern agriculture has replaced ecosystem services with exogenous inputs such as fertilizers, irrigation, tillage and pesticides (Duru et al., 2015; Rist et al., 2014). This has resulted in human-modified and intensive agricultural systems that are relatively independent of their natural biophysical context (Rist et al., 2014) and harm the environment (Emmerson et al., 2016). For example, the development of irrigation helped to manage drought or high evapotranspiration and consequently increase yields (Zaveri and Lobell, 2019), but the subsequent depletion of water resources can lead to substantial local to regional water scarcity.

While it is well known that intensification has positive impacts on productivity and often negative impacts on the environment (Therond et al., 2017), few studies have analyzed its effects on the dynamics of the performances of agricultural systems. The recent meta-analysis of Knapp and van der Heijden (2018) on the effect of conventional, organic and conservation agriculture on yield stability showed contrasting effects depending on the crop, pedoclimatic conditions and intensification level, and on the metric used to analyze stability (standard deviation (SD) or coefficient of variation (CV); see also Li et al. (2019)). They highlight that the causes of yield stability remain unexplored. Kirchmann et al. (2016) indicate that comparing agricultural systems, such as conventional and organic, requires sound "conditions for equitable evaluations…to avoid biased design, inappropriate interpretations and flawed conclusions" (see also Gattinger et al. (2012)). Therond et al. (2017) point out that conventional agriculture, like organic agriculture, covers a great diversity of cropping systems and thus the true determinants of performances (including dynamics).

Recent key studies have focused on effects of diversity on dynamics of agricultural systems (Dardonville et al., submitted; Wang et al., 2019). To our knowledge, however, there is no summary of effects of intensification that addresses problems related to comparing broad categories such as conventional vs. organic agriculture. Consequently, we performed a systematic review of peer-reviewed articles that quantified effects of intensification on the vulnerability, resilience and robustness (VRR) – i.e. dynamics – of agricultural systems facing climatic and economic disturbances. This paper presents the main results of the review and discusses them in light of recent studies that address these issues. This analysis complements those of effects of diversity on VRR (Dardonville et al., submitted) and of the nature of studies that investigate VRR of agricultural systems (Dardonville et al., submitted).

Methods

To identify relevant studies, we ran the following query [vulnerability, resilience or robustness × agricultural system × quantitative evaluation] on the Web of Science Core Collection (WoS) for English peer-reviewed articles from January 1988 to July 2018):

TS = ((vulnerabilit OR resilien* OR robustness) AND (agri* OR agro* OR crop* OR farm* OR grass* OR pastor*) AND (indicator* OR evaluat* OR quantitativ* OR quantif* OR model* OR simulat* OR decrease OR increase OR assess*))*

The search initially identified 10,635 articles. After focusing on articles involving temperate climate zones, to collect results with similar ecological and socio-economic functioning, 3,542 articles remained. To exclude studies outside the scope of the review, we first sorted by journal and WoS category. We then used VOSviewer software to systematically sort the studies based on the co-occurrence of terms (n=10) to identify terms that excluded studies outside the scope (1,434 articles remained). Finally, two reviewers read the title and abstract of each remaining article, which yielded 37 articles that quantified the VRR of agricultural systems in temperate zones at the field, farm or regional level. The sub-sample of articles that addressed effects of intensification on VRR was analyzed for the present review (11 articles).

To summarize the results of the articles, we used the generic analytical framework developed by Dardonville et al. (submitted). For each article, we specified (i) the disturbance that occurred (VRR "*to what disturbance*"), (ii) the spatial and temporal resolution and extent of the study (VRR "*when and where*"), (iii) the type and organizational level of the agricultural system investigated (VRR "*of what agricultural system*"), the performance attribute that was important to maintain (VRR "*for which performance attribute*"), whose dynamics were described using criteria of dynamics (e.g. variability, trend), and the endogenous or exogenous characteristics and properties of agricultural systems that resulted in VRR (VRR "*due to which explanatory factors*").

Each result of each article was extracted and homogenously coded for each combination of disturbance, type of production, organizational level, performance attribute, criterion of dynamics and explanatory factor. The analysis yielded 145 results from 11 articles that focused on intensification (of agricultural practices or socio-economic levels) as an explanatory factor (*Table S 1*).

Results

Only 11 articles were identified that quantitatively addressed effects of intensification on the VRR of agricultural systems. Five articles (56 results) focused on crop systems, three (47 results) on livestock systems, one on grassland systems (2 results), one on vineyard systems (35 results) and one on all agricultural systems (3 results). The articles varied greatly in the type of agricultural system (crop, livestock, grassland, vineyard), organizational level (field, farm, region) and performance attribute (e.g. yield, economic efficiency, quality of production) (Dardonville et al., submitted). The three articles that studied livestock systems analyzed different performance attributes (economic efficiency of production, self-sufficiency in forage and ability to feed the herd each day, Bouttes et al., 2018; Martin and Magne, 2015; Sabatier et al., 2015). Focusing only on results with the same characteristics (i.e. performance attribute and type of production), we summarized those with intensification as an explanatory factor for yield performance (9 of the 11 articles) of crop systems (5 of the 11 articles) when climate variability and change occurs (10 of the 11 articles). Consequently, we focused on five of the 11 articles (i.e. 56 of the 145 results) that studied crop yields for systems subjected to climate variability and change. Due to the small sample size, we performed cross-sectional analysis regardless of the organizational level. The five articles used different criteria for the dynamics of performance attributes: level, trend, variability and probability of exceeding a given threshold (i.e. high or low yield).

The explanatory factors of intensification described in these five studies were the intensity of practices (soil tillage, pesticide use, fertilizer use, irrigation), the level of capital, the economic size of the farm (quantity or value of outputs) and the quantity of labor (number of individuals in the household) (Gaudin et al., 2015; Matsushita et al., 2016; Reidsma and Ewert, 2008; Reidsma et al., 2008a; Urruty et al., 2017).

When analyzing effects of intensification factors on crop system dynamics (Figure 23), we distinguished effects on the yield itself (i.e. productivity) from those on the dynamics of yield (e.g. variability, trend). As expected, a clear positive effect was observed for intensification of agricultural practices (pesticide use, fertilization, use of soil amendments, irrigation and tillage) on yield at the field level (Gaudin et al., 2015; Urruty et al., 2017).

Effects of intensification factors on the dynamics of yield were less clear. Of the 145 results, 67% were negative or neutral, suggesting that intensification is not a relevant strategy to stabilize (i.e. achieve low variability in) yield, increase the trend in yield or have a high probability of a high yield.

Fertilization, pesticide use, irrigation and tillage had variable effects on the variability and trend in yields at field, farm and regional levels. For example, Urruty et al. (2017) showed that intensive fertilization had no effect on the trend in yield at the field level, while Matsushita et al. (2016) showed a positive effect of chemical fertilization on the short-term trend in yield at the regional level. Effects of fertilization and irrigation are difficult to distinguish since they are strongly related: increasing one leads to higher crop demand for the other. Reidsma et al. (2008a) showed that effects of fertilization and irrigation at the regional level depended on the country investigated.

Farm economic size had a negative effect on the variability (i.e. stabilization) in yield at the regional level (Reidsma and Ewert, 2008). However, the effects fluctuated between positive and negative for the trend in yield at the farm level (Reidsma et al., 2008a). Household size had no effect on the trend in yield at the regional level, but capital had a positive or neutral effect on it (Matsushita et al., 2016).

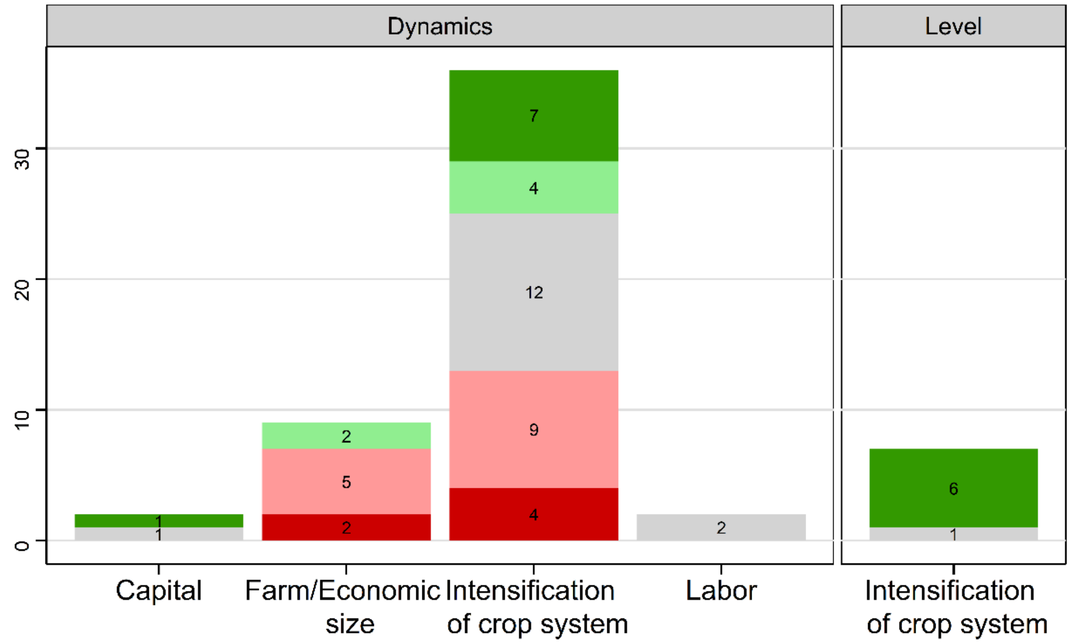

Figure 23. Number of results indicating the direction of the effect of climate variability and change and economic disturbance on the desired level (high) and dynamics (resilient) of yield for crop systems. Desired dynamics include an increasing trend, low variability and high probability of a high yield. When differences in results could be tested statistically, they were considered significant at p<0.05.

Discussion

This review highlights that few articles tested whether intensification influences the VRR of agricultural systems. Only five articles remained when the corpus was reduced to those that studied the same set of characteristics. The articles addressed the classic subjects of effects of climatic and economic variability on yield performance in crop systems. Only one article each addressed grasslands or vineyards, while the three articles that addressed livestock systems could not be compared directly since each examined a different performance attribute. Nonetheless, we discuss their results in light of those for crop systems.

We found clear positive effects for intensification of input use (including tillage) on crop yield. Overall, however, we also found that input intensification was not effective at mitigating negative effects of climate change and economic variability on the dynamics of crop yield, regardless of the organizational level. These results agree with those for livestock systems. Bouttes et al. (2018) showed that intensification of practices (percentages of maize and concentrates in diets, stocking rate) in livestock systems resulted in a high yield but a decreasing trend in economic efficiency of production. Martin and Magne (2015) showed more variable results because the seasonality of climate events can favor or disfavor grazing-based or maize-silage-based (more intensive) systems. Sabatier et al. (2015) showed that a low stocking rate, and thus intensity of grazing, led to fewer overgrazing situations and thus less “collapse”.

Similar to intensification of input use, intensification of capital and labor seemed to have no clear effect on the trend in yield, regardless of the organizational level. Reidsma and Ewert (2008) and Reidsma et al. (2008a) showed that farms with the largest economic outputs seemed more sensitive to high temperatures at the regional level, and to high temperatures and subsidies at the farm level. In these studies, the economic size of the farm can be considered a proxy of capital intensification, in the sense that larger economic size is usually based on a large farm area or quantity of equipment (Bardaji and Iraizoz, 2015).

Our results contribute to the general debate on intensification. As mentioned, effects of intensification on the dynamics of yield depend strongly on the “production situation” (Aubertot and Robin 2013). Reidsma et al. (2008b) showed that the effect of irrigation on yield depended mainly on water availability, fertilization level and crop type. Recently, Renard and Tilman (2019) revealed that yield stability is increased by irrigation, but more so by species diversity and even more so by diversity in crop functional groups (legume, cereal). They claim that diversification could be a better strategy for adapting to climate change than irrigation in countries where water is unaffordable or insufficient. This indicates that the type and management of crops must be adapted to local production situations, including (water) resources (Aubertot and Robin, 2013; Knapp and van der Heijden, 2018; Zaveri and Lobell, 2019).

The dynamics of yield can depend on the level of production (Knapp and van der Heijden, 2018; Reidsma et al., 2008b; Stampfli et al., 2018; Wang et al., 2019)(Figure 24). For example, Reidsma et al. (2008b) showed that farms with lower yields (and less intensification) were less sensitive to climate disturbance in regions that had already adapted to recurring drought and increasing temperatures (e.g. Mediterranean regions). For grasslands, Figure 7 of Wang et al. (2019) showed that higher productivity led to significantly higher variability (SD) in productivity. These results may be explained by effects of biomass quantity on demand for and availability of resources required for growth (Figure 24). Biomass quantity, associated with yield, determines a crop’s water and nutrient demands: the more biomass it has, the higher its water and nutrient demands are. The availability of soil water and nutrients determines whether these demands are met or not. Both demand for and availability of water and nutrients influence each other. When water is scarce, rainfed systems with high production are expected to be more sensitive to climate variability, which influences variability in soil water availability. If these systems are irrigated and water for irrigation is available, however, they can maintain high production. Addition of nutrients can also maintain production, but Rist et al. (2014) call this maintenance of resilience through human inputs “coerced resilience”.

Knapp and van der Heijden (2018), Li et al. (2019) and Wang et al. (2019) assert that results can differ depending on whether an absolute (i.e. SD) or relative (per unit of yield, i.e. CV) indicator of stability is used. For example, Knapp and van der Heijden (2018) showed that organic and conventional farming had the same absolute stability in production, but that organic farming had lower relative stability due to lower production (-16%). In their results, higher yield led to higher relative stability, which seems to contradict the theoretical principles mentioned previously about relations between yield and its dynamics. However, the authors did not test effects of irrigation or specify the type of disturbance (e.g. drought) that occurred during the study period of nearly 4 years. It is possible that the conventional and organic systems they compared did not have the same level of intensification (e.g. irrigation). Accordingly, when comparing the VRR of a system’s yields, it is necessary to consider its production level and crop management to ensure the analysis provides relevant results and avoids classic pitfalls when comparing systems that can differ greatly, such as conventional vs. organic (Kirchmann et al., 2016).

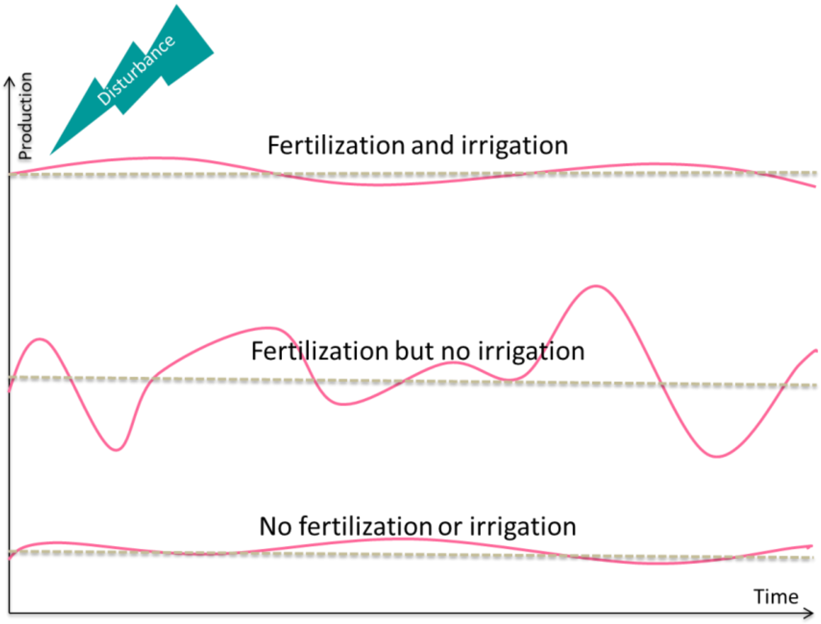

Figure 24. Diagram of the effect of production level and input intensification on production variability of a crop/grassland system at the field level due to resource availability (water, nutrients) for a given climate and soil. Without fertilization or irrigation (bottom), the associated low yield (low biomass) leads to low plant water demand that is met by soil water availability, and thus few climate effects on yield dynamics. With fertilization alone (middle), the higher yield and biomass increases plant water demand, making yield dynamics more sensitive to climate variability. With fertilization and irrigation (top), the higher yield and biomass increase plant water demand, which is met by irrigation, making yield nearly insensitive to climate variability (when irrigation water is not limited). It shows that if intensification of practices and production level are not considered, the top and bottom situations have similar yield dynamics (low sensitivity to climate variability) but different explanatory factors.

While some agricultural practices can provide desired dynamics of yield (e.g. positive trend) in the short term, it is necessary to consider long-term effects (Coomes et al., 2019). Matsushita et al. (2016) and Zaveri and Lobell (2019) showed that fertilization and irrigation each increase yield trends in the short term but that this effect tends to disappear in the longer term, perhaps due to yield stagnation. Consequently, short-term studies may be unable to identify or highlight middle- or long-term effects (Müller et al., 2016).

From a long-term perspective, the dynamics of soil natural capital and local resources (e.g. water) also have a major influence on the VRR of agricultural systems (Weyers and Gramig, 2017; Dardonville et al., submitted; Rist et al., 2014). Agricultural systems can exhibit VRR in the short term (e.g. season, year(s)) while experiencing degradation in soil natural capital and local resources due to intensive management and high production. For example, intensive use of groundwater for irrigation can result in a water shortage that renders irrigation more difficult (costlier) or even impossible (de Graaf et al., 2019). This also occurs in agricultural systems that use soil natural capital without recycling it, such as those that deplete soil organic matter (Drinkwater and Snapp, 2007) or organic systems that use the soil phosphorus reserve without supplying organic matter to replace the phosphorus exported (Kirchmann et al., 2009; Oelofse et al., 2010).

Although less intuitive, dynamics of resource use in agricultural systems can influence yield dynamics over the long term. Efficient resource acquisition during a given period (e.g. by exploring soil horizons (Barkaoui et al., 2016)) can initially lead to higher biomass production or stability (e.g. at the beginning of a season) but also greater depletion of soil resources. If the disturbance (e.g. drought) lasts or repeats, the empty resource reserves (e.g. soil water or nutrients) and the large amount of biomass with high water and nutrient demands will become factors influencing vulnerability in the medium term (e.g. at the end of the season) (Zavalloni et al., 2008).

Conclusion

Debate on the VRR of agricultural models is far from over, both on effects of intrinsic diversity (Dardonville et al., submitted) and those of intensifying production by adding organic or chemical inputs (as indicated by recent articles that compare conventional and organic systems). In this review, we summarized results of articles that explicitly quantified effects of intensification on the VRR of agricultural systems. The articles reviewed focused mainly on effects of climate on dynamics of yield. We show that intensification, although ensuring higher crop yields, is not always a reliable strategy to support resilience to disturbances. We highlight two key methodological issues when analyzing the VRR of agricultural systems. First, it is necessary to consider the production level (and its type) and the intensification level because they determine the dynamics of water and nutrient availability and thus the effects on production. Second, short-term studies may not be able to identify middle- or long-term effects of intensification on endogenous (e.g. soil water content) or exogenous (e.g. local water resources) resources and, in turn, on the VRR of agricultural systems. Intensification may have a positive effect in the short term, but degrading natural capital creates a negative feedback loop in the longer term (Dardonville et al., 2019; Rist et al., 2014). Accordingly, considering the characteristics of production situations (crop, management, soil, climate) and local resources is necessary to design resilient agricultural systems. More than ever, the question of intensification level and, more broadly, production level, needs to be reintegrated into the design process. Society needs to take a position about the objectives set for agricultural systems, deciding whether it is willing to sacrifice environmental quality and resilience in return for high yields. In the quest for agricultural sustainability in the most productive zones in the world, it may be necessary to redefine objectives: less focus on the production level and more focus on the desired dynamics, especially in the current context of climate change and increasingly extreme climatic events (Tittonell et al., 2016).

Supplementary material

Table S 1 : The 11 articles selected, detailing the type of production, organizational level, disturbance (categorized), performance attribute (categorized) and explanatory factors.

Reference	Prod. type	Org. level	Disturbance	Attribute	Explanatory factors
Bardaji and Iraizoz, (2015)	Wine	Farm	Climate variability and change	Yield, quality of production	Capital, labor, intensification of wine production, adaptation
Bouttes et al., (2018)	Mixed	Farm	Climate variability and change	Yield, economic efficiency of production	Economic performance, intensification of livestock system, composition effect, farm diversity, livestock structure
Gaudin et al., (2015)	Crop	Field	Climate variability and change	Yield	Diversity of rotation, intensification of crop system, composition effect
Martin and Magne, (2015)	Mixed	Farm	Climate variability and change	Self-sufficiency in forage	Intensification of livestock system, adaptation
Matsushita et al., (2016)	Crop	Region	Climate variability and change	Yield	Policies, composition effect, capital, intensification of crop system, labor, taxonomic diversity

Reidsma and Ewert (2008)	Crop	Region	Climate variability and change	Yield	Response diversity, farm diversity, farm/economic size, intensification of crop system
Reidsma et al., (2008b)	Crop	Farm	Climatic and economic variability	Yield	Intensification of crop system, farm/economic size, composition effect, adaptation, policies, farm/economic size
Sabatier et al., (2015a)	Grassland	Field	Climate variability and change	Ability to feed the herd each day	Continuous or rotational grazing, intensification of livestock system
Salvati, (2010)	All	Region	Land degradation	Yield	Composition effect, labor
Stampfli et al., (2018)	Grassland	Field	Drought	Yield	Intensification of grassland use
Urruty et al., (2017)	Crop	Field	Climate variability and change	Yield	Intensification of crop system, sowing practices, cultivar characteristics, diversity of rotation, composition effect, adaptation

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WHAT PROSPECTS FOR WORK IN AGRICULTURE IN THE WORLD?

Benoît Dedieu

INRAE, France

Abstract: 1.3 billion people work in agriculture (family farmers, salaried workers), i.e. 27% of the world's active population (2018). The number of agricultural workers is expected to remain stable in the coming years. Researches on work in agriculture remain rather disciplinary (economics dealing with labor markets, ergonomics with occupational health, sociologists with family farming and rural development or with the emergence of new figures of the profession…). Given these conditions, how can we produce a consolidated vision of the future of work in agriculture on a global scale? This was the objective of the 2nd International Symposium on Work in Agriculture entitled: 'Thinking the Future of Work in agriculture' (29 March – 1 April 2021). The dynamics of development of agriculture in the North (OECD) contrast with those in the Global South and thus raise different issues. Is an "agriculture without farmers" the future in the North (with salaried people in very big estates) considering the regular decrease of the number of farms and of active population? In the South, decent work (from the ILO definition) is still a target point for a significate part of the agricultural workforce. Beyond these deep differences, some issues appears to be transversal. The agroecological transition is everywhere a change in the farming style and a change in work organization, and in working conditions that have to be studied for different categories of workers (man, women, young, wage-earners). The digital revolution will certainly support the smart industrial agriculture but may be useful in agroecological – family situations. Migration is also a major phenomenon, from rural areas to cities, from poor countries to rich ones, often leading to precarious and hard-working jobs. What are the perspectives for a research agenda? First, decent and attractive employment is one key point for the future. Job satisfaction indicators (including self-fulfillment) are to be deepen notably to foster youth (in the South) and new incomers (OECD) interest for farming. Second, there is a need to considering the co-evolution of structural and social drivers (enlargement of farms, societal recognition of farmers…), on farming's new set of specifications (ecologization of practices) and on digital opportunities. Third agri-chains and territorial approaches of work should be enhanced.

BUILDING FARM SYSTEM RESILIENCE IN CANTON VAUD

Ulysse Le Goff, Dominique Barjolle, Johan Six

Institute of Agricultural Sciences, Swiss Federal Institute of Technology in Zurich (ETHZ)

Introduction

Climate change is a challenge that affects particularly agriculture, which both is a cause of it and suffers from it. The mission of agriculture is basically to produce enough food for today and for future generations. The mission does not change but is facing a new context, with the ending of certain resources, and new restrictions in relation with the urgent need to contribute to mitigate the climate change (Paris Agreement). Swiss agriculture within the global food system already faces and will face even more in the future, the consequences of climate change, such as climate shocks (droughts and floods for example) or price volatility. Indeed, the whole Alpine area is more exposed to changes and disturbances than other parts of Europe due to the global warming (Hoegh - Guldberg O et al., 2018).

To provide guidance for farmers and facilitators to cope with this harsh situation, it is necessary to embrace complexity and change. In the agricultural research and the practitioner sector, the "Resilience" framework gained influence recently to address this challenge (Darnhofer, 2014; Tendall et al., 2015). In an agricultural context, resilience thinking implies that farms can co-evolve with their context and adapt to a changing external system/environment (Darnhofer, Fairweather, & Moller, 2010). Thus, a resilient farm system can buffer shocks (Folke et al., 2010) or even transform into a new system, with new processes, when the old, existing system cannot be sustained any longer (Walker, Hollin, Carpenter, & Kinzig, 2004). This means that a resilient farm system will be able to persist over time albeit unforeseen shocks or disturbances, but will not necessarily rebound and return its original state as it will continue to evolve and adapt.

To strengthen farm system's resilience, it is important to identify and assess where vulnerabilities rely. However, resilience measurement is especially difficult for complex systems, and a Socio-Ecological System (SES) (in our case farm systems), with its diverse dynamics and influences is particularly challenging (Choptiany et al., 2016). Different resilience tools already exist focusing on different aspects and scales (Barron, Douxchamps, Debevec, Giordano, & Barron, 2017). One of the resilience measurement tools for an agricultural context was developed by the Food and Agriculture Organization of the United Nations (FAO); it is called the 'Self-evaluation and Holistic Assessment of climate Resilience of farmers and Pastoralists' (SHARP[49]). The tool builds upon the IPCC definition of resilience (IPCC 2014): "the capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation".

SHARP-based assessments aim at strengthening resilience through an approach built on flexibility, learning and the knowledge of farmers themselves (Choptiany, Phillips, Graeub, Colozza, & Dixon, 2015). It is both a quantitative and a qualitative measurement tool, since it considers the perceived and expressed needs of farmers. This is possible because it works on household level and on a participatory basis in close cooperation with the farmers (Choptiany et al., 2016). Information is generated and analyzed with the farmers on site. Inadequacy in understanding the local context often leads to the failure of agricultural extension services, especially in Africa (Isubikalu, 2007). To avoid this bias, the SHARP-tool was designed in a trans-disciplinary manner, including technical experts, academia, extension services and local farmers and works to empower agricultural producers to self-assess their resilience and provide direct inputs into the results (Choptiany et al., 2016). In the SHARP-approach, it is recommended that a facilitator supports the farmers in completing the SHARP survey and in disentangling their resilience scores. To strengthen farm system resilience, the emphasis is put in using

[49] See http://www.fao.org/in-action/sharp/en/

and building upon local knowledge. Since the first implementation of SHARP in 2013, the tool has been adapted to and used in over 18 different countries to assess, monitor and evaluate resilience (FAO 2018).

In Switzerland, the tool has been adapted with the help of local experts' knowledge, and feedback from farmers through a pilot study with 25 farmers (Diserens et al., 2018).

In this paper, the authors focus on a selection of relatable farming systems and the resulting resilience assessments, as well as overall key issues brought forth by the assessment tool and discussed with farmers during group workshops.

The research question explored in this article is thus, based on a case study around two oppositely diversified farming systems in Canton de Vaud: *RQ - How is resilience built differently between different farming systems in a same region?* Two hypotheses will be discussed. *H1: "The overall resilience is higher for more diversified farming systems"* and *H2: "Diversified farming systems tend to have a stronger focus on agroecological practices while more specialized farming systems may have a stronger focus on diversifying their selling channels".*

1. Canton Vaud context

Canton Vaud agriculture and challenges

Switzerland is divided in three main geographical areas: the Alps, the Swiss Plateau and the Jura (Fig 2.). Each region has a rather distinct climate and its own agroecological zone (AEZ). The Canton Vaud is situated in the South-West of the Switzerland and is a good representation of the Swiss geography as it embodies all three distinct regions described above. It encompasses high peaks and mountains rising up to 3,210 m, as well as plains and lakes at low altitudes (EDA online 2018).

In the plain region of the Canton ("plateau"), the cropping systems include staple crops, vegetable and fruit production as the climate in this region is particularly suitable for them with a long vegetation growing period and temperate rainfall. This is in contrast to the situation in the mountainous Jura and Alps regions, where the vegetation growing period is rather short, which allows for mainly pasture and animal production (AGRIDEA 2011, Schulz et al. 2018)). The dynamic between mountains and plains takes an important place. Nevertheless, field crops remain important for Vaud as more than half of the agricultural area is dedicated to them. Thus, Vaud has a really rich and diversified agriculture.

Figure 25: Map of Switzerland displaying the three main regions (green: Jura, yellow: Swiss Plateau cultivated mostly with open field crops and brown: Alps) and the borders of the Canton Vaud (in black). Adapted from Office Fédéral de l'environnement, 2008. Photo credit: U. Le Goff

In the context of economic instability and loss of attraction of agriculture, the number of farms has considerably decreased over the last 40 years dropping from 111,000 in 1975 to 51,600 in 2017. In parallel, the average area of these farms has almost doubled to reach 20 ha. In contrast, organic farming is increasing and now 14% of Swiss farms are organically certified (OFS, 2017). Organic farms are economically better off in terms of financial sustainability (Sanders et al., 2014; van der Ploeg et al., 2019). Like organic agriculture, other systems of production ("integrated production", very similar to integrated pest management) that are more environmentally sustainable are gaining importance on the domestic market. This diversification is opposed to the specialization promoted by policies and the need of doing structural economic changes to reduce cost in the past years (Knickel et al., 2018).

The Vaud agricultural policy promotes subsistence and quality agricultural production, which is environmentally sustainable and provides sufficient economic remuneration for the farmers (Blättler, 2016). The Vaud agriculture must meet the needs of the market and society as written in the agricultural policy (LAgr and RAgrEco 2010). Therefore, agriculture is in a delicate position, because it is subject to market uncertainties and economic constraints like price volatility and low competitiveness in comparison with other countries, as well as to the societal changes (pressure to reduce drastically chemical pesticides and fertilizers, increasing demand for organic and local food, etc.).

In Vaud, as in Switzerland overall, agriculture is facing major challenges. Climate change is becoming a significant issue for farmers along with other challenges that threaten the agricultural production and the economic stability of Swiss agriculture. These issues are notably the opening of the Swiss borders to international products and the increase in urbanization that could lead to great disturbances. In his report on Swiss French agriculture conducted in 2016 Blättler (2016) recommends to implement tools and measurement to address the growing uncertainties concerning agricultural prices and climate change. As a matter of fact, even in a wealthy country like Switzerland, agriculture can be highly affected by globalization and climate change. In 2018, the consequences of climate change were already seen in Vaud: the heavy drought has been especially detrimental to mountain pasture and rain-fed crops (e.g. vine, field crops and arboriculture) (USP online 2018). Emergency assistance was put in place to provide water for the cattle on the mountain pastures in conjunction with a decrease in border taxes on animal feed.

2. Tools and methods

Farm system resilience assessments

A set of 69 questions asked in face-to-face and remote surveys and related to the 13 behavior-based resilience indicators identified by Cabell & Oelofse (2012) have been taken as basis for the resilience assessment, together with their individual scores. The computation of the 13 indicators was conducted by merging the different SHARP question scores by following the methodological framework in (Choptiany et al., 2015). The 13 indicators integrate multiple aspects from different question areas to provide a comprehensive assessment of resilience.

Figure 26. The adaptive cycle and Cabell and Oelofse's 13 agroecosystem indicators

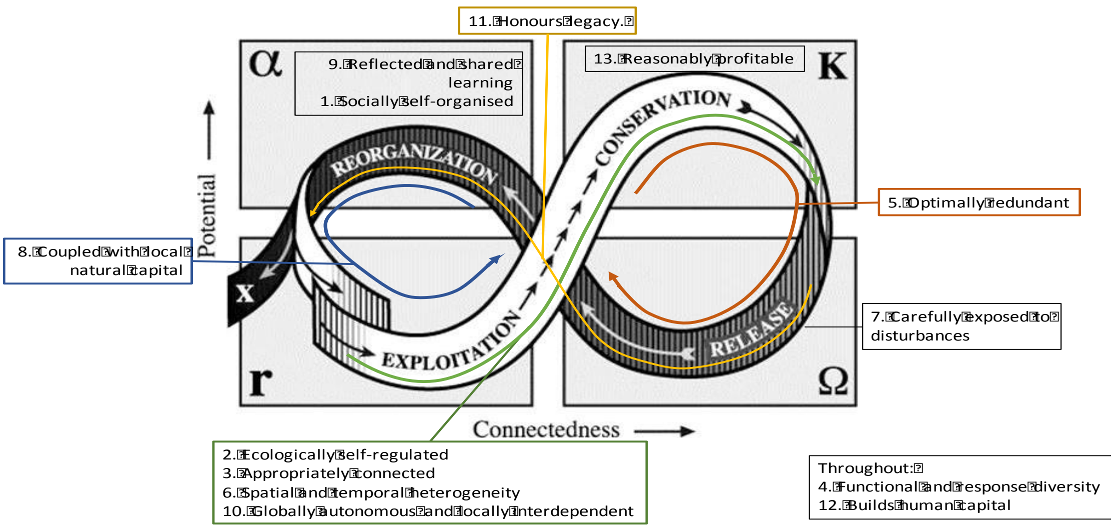


Table 1: Indicators along the adaptive circle

Adaptive cycle phase	Agro-ecosystem indicator	Features	Rating criteria* Switzerland
Release (Ω)	7: Exposed to disturbances	The system is exposed to discrete, low-level events that cause disruptions without pushing the system beyond a critical threshold	New varieties & breeds, crop & livestock losses, information/education, buffer zones, weed management, dealing with disturbances
Release (Ω) to Reorganization (α)	1: Socially self-organized	Farmers and consumers are able to organize into grassroots networks and institutions such as co-ops, farmer's markets, community sustainability associations and advisory networks	Group membership, crop & livestock losses, access to water, dealing with shocks, community cooperation, previous collective action, access to markets
	9: Reflective and shared learning	Individuals and institutions learn from past experiences and present experimentation to anticipate change and create desirable futures.	Household composition, record keeping, access to information, governmental policies, group membership, disturbances
	11: Honors legacy	Maintenance of heirloom seeds and engagement of elders, incorporation of traditional cultivation techniques with modern knowledge	Household composition, production forms, trees & agroforestry, information/education
Reorganization (α) to Exploitation (r)	8: Coupled with local natural capital	Builds (does not deplete) soil organic matter, recharges water, little need to import nutrients or export waste	Land management practices, livestock practices, trees & agroforestry, synthetic pesticides use, water conservation, water quality, soil quality, presence of legumes, energy conservation, fertilizer use
Exploitation (r) to Conservation (K)	2: Ecologically self-regulated	Self-regulated pest management (usage of predators or parasitoids), use of ecosystem engineers, and align production with local ecological parameters	Crop production, new varieties & breeds, trees & agroforestry, synthetic pesticides use, access to water, presence of legumes, buffer zones, energy sources, energy conservation, fertilizer use
	3: Appropriately connected	Collaborating with multiple suppliers, outlets, and fellow farmers; crops planted in polycultures that encourage symbiosis and mutualism	Seed & breed sources, access to information, intercropping, veterinary access, community cooperation, previous collective action, information & communication technologies, market information, market access (buying/ selling), price stability

	6: Spatial & temporal heterogeneity	Patchiness on the farm and across the landscape, mosaic pattern of managed and unmanaged land, diverse cultivation practices, crop rotation and in association	Crop production, trees & agroforestry, intercropping, land ownership, soil quality and soil management
	10: Globally autonomous & locally interdependent	Less dependence on commodity markets and reduced external inputs; more sales to local markets, reliance on local resources; existence of farmer co-ops, close relationships between producer and consumer, and shared resources	Livestock nutrition, new varieties & breeds, animal diseases, land ownership, energy sources, weed management, collective action, local farm input, direct marketing, market access (buying)
	13: Reasonable profitable	Farmers and farm workers earn a livable wage; agriculture sector does not rely on distortionary subsidies	Productive assets, insurances, main income sources, external income, savings, investments, financial resources, stakeholder interactions, market access (buying)
Conservation (K) to Release (Ω)	5: Optimally redundant	Planting multiple varieties of crops rather than one, keeping equipment for various crops, getting nutrients from multiple sources, capturing water from multiple sources	Crops, livestock nutrition & practices, new varieties & breeds, trees & agroforestry, access to water, land management, energy sources, fertilizer use, group membership, productive assets, market access (buying & selling)
Throughout the Cycle	4: Functional & response diversity	Heterogeneity of features within the landscape and on the farm; diversity of inputs, outputs, income sources, markets, pest controls, etc.	Production types, aquaculture, crop and livestock practices, trees & agroforestry, animal diseases, pest management, buffer zones, weed management, main income sources, market access (buying & selling)
	12: Builds human capital	Investment in infrastructure and institutions for the education of children and adults, support for social events in farming communities, programs for preservation of local knowledge	Household composition, infrastructure, synthetic pesticides, water quality, land management, legumes, buffer zones, fertilizer, group membership, food

Representative sampling through a k-medoids clustering

Due to its diversity of environments and agricultural productions, the Canton Vaud presents a wide range of farming systems. Capturing this diversity through a typology is crucial for understanding the farming system. (Dixon, Gulliver, & Gibbon, 2001; Kuivanen et al., 2016). We thus aimed at simplifying this complexity by identifying a small number of farming systems (<20), i.e. structurally similar farms in terms of productions and size so that we could get insight on resilience for each of these farming systems.

Farm systems are a part of a complex network of social and ecological interactions comprised of environmental, economic, social and political factors (Ikerd, 1993; Moller, Darnhofer, & Fairweather, 2008), and can be considered as a SES (Ostrom, 2009). A farming system (FS) is comprised of multiple, individual farms with similar resources, production patterns and external conditions (Darnhofer, Gibbon, & Dedieu, 2012; Dixon et al., 2001). It must be mentioned, that for this paper, the farms in each farming system are grouped according to their productive surfaces and livestock and may show large variations, e.g. the production patterns or the resource bases vary among FSs. Nevertheless, farms were grouped into FSs, under the hypothesis that FS' complexity may be the most decisive factor for measuring resilience (Bennett, Cumming, & Peterson, 2005; Carpenter, Bennett, & Peterson, 2006; Darnhofer, 2010).

The identification of FS was carried out using the Vaud Acorda® public dataset from 2016. This dataset is collected annually to register all surfaces cultivated by farmers as well as livestock in order to direct government subsidies. It comprises more than 150 variables for 3,284 farmers (as of 2016). Unregistered farms were thus ignored from this study; these correspond to a few large agricultural wine and pork companies integrating the whole value chain and numerous small producers doing this often as a hobby (*e.g.* <1,000m² of vine). Preliminary work was carried out to group variables according to similarities in terms of technical-economic impacts on the farm. This work was carried using local literature and local expert interviews (administration, extension services, farmers, etc.). 14 surface items and 6 animal items resulted from this preliminary work. Some variables were kept as informative variables.

Based on this data, a cluster analysis was carried on all 20 variables and 3,184 farms to group farms in FSs. We conducted this using a k-medoids clustering algorithm using the R software program. The process for determining k (the number of clusters) was a back-and-forth discussion with experts and analysis of resulting clusters. Although our first aim was to reach a k between 10 and 15 to make it easier to present and use, we had to go up to 22 different clusters due to the wide diversity of situations existing in the Canton, which local experts considered an accurate representation of the diversity of farming systems in the Canton.

Table 17: Cluster analysis results in 22 FS

FS number	Name given (based on a post-clustering analysis)	Interviewed	Amount of farms comprised
1	Small-size pasture-based livestock farm	8	397
2	Mid-size crop pasture-based livestock farm	19	343
3	Mid-size cereal growers	8	303
4	Dairy farms with large herds	8	289
5	Mid-size cereal and beet growers	5	244
6	Small-size vineyards	6	228
7	Above average-scale cereal farms	5	178
8	Meat cattle farms	4	174
9	Permanent grassland farms	5	173

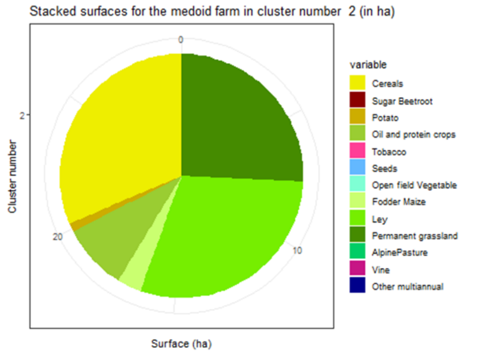
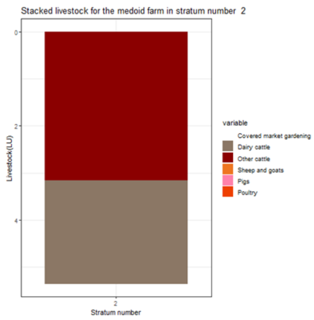
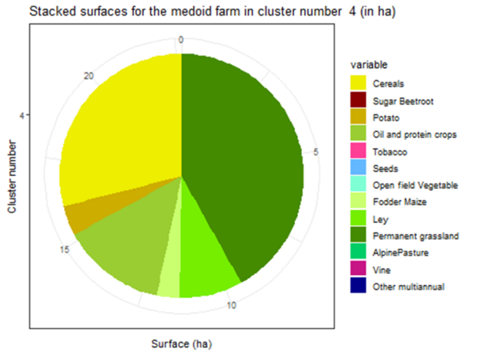
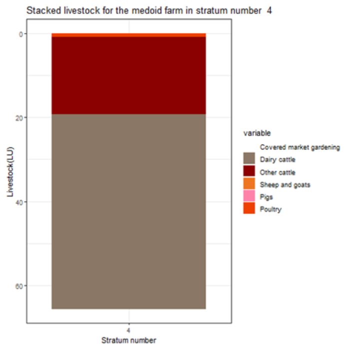
10	Large beet and cereal farms	6	151
11	Fodder producers	5	133
12	Large pasture-based dairy farms with limited livestock	4	114
13	Transhumant dairy farms	5	99
14	Beet and potato farms	6	95
15	Large vineyards	1	90
16	Horse farms	5	76
17	Poultry farms with limited surface	7	58
18	Seeds and cereals farms	6	54
19	Tobacco farms	5	34
20	Sheep and goat farms	4	25
21	Fruit tree farms	0	16
22	Pig farms	0	10

Choice of farming systems for comparison

The focus in this paper is on two typical farming systems in the Canton, corresponding to the second and fourth most numerous clusters (343 and 289 farms) resulting from the cluster analysis. Since the FSs were created based on the surface areas and livestock units, and centered around existing farms (*medoids*), they may sensibly be described by the corresponding values for the medoid farms. The two FSs use roughly the same land area (around 25-30 ha) in a similar way (>50% pastures) but a major difference lies in the degree of specialization in dairy production; farms included in FS2 usually include cattle but to a rather low level (<6 LU in the medoid farm) while FS4 is characterized by a relatively large dairy cattle herd (>60LU for the medoid farm), which is the highest medoid value among all FS. This difference can be expected to have major impacts on the resilience of both FSs as it may reveal major differences in the strategy used by farmers in both cases to reach their own objectives. Farms in FS2 can be expected to meke use of extra activities to maintain sufficient revenues (direct selling, part-time job outside the farm, etc.) while the FS4 may have focused on decreasing marginal costs through investing in larger facilities.

The choice of FSs analysed here is motivated first by frequent and recent droughts in Switzerland (notably 2015 and 2018) during summer. These can have largely affected grassland productivity (Meisser et al., 2013) and cattle owners, although emergency measures from the Canton helped reduce the impact. This choice is also motivated by the recurring difficulties encountered by the dairy producers in Switzerland to reach decent revenues from milk, especially for those selling to industrial processers outside of the Protected Designation of Origin (PDO) productions.

Figure 27: Medoid farms UAA and LU distribution for FS2 and FS4

<table>
<tr><th>Medoid farms (2016)</th><th>Utilised Agriculture Area distribution</th><th>Livestock Units distribution</th></tr>
<tr><td>FS 2</td><td>
</td><td>
</td></tr>
<tr><td>FS4</td><td>
</td><td>
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</table>

Although FS4 from this data may seem to be more diversified, as it includes more cattle for an overall similar set of crop and grassland productions, we here consider it to be the more specialized one. Indeed, most of the production from grassland and crops in FS4 are likely to be destined for cattle feed and milk production may eventually be overwhelming over other outputs.

Farmers from both farming systems were interviewed within the project (19 from FS2 and 8 from FS4).

Discussion workshops

Discussion workshops were held to help address the issues identified with the lowest resilience scores in each region. In each case, the 5 or 6 least resilient aspects at the regional level were proposed for the group discussion. As a reminder, the importance scores were also presented. Where possible, only the scores corresponding to the participants in the discussion session were taken into account. Collectively, 3 aspects were chosen each time, on which each participant could contribute to explain the causes of these relatively low scores of resilience and develop possible solutions to improve the situation.

3. Results

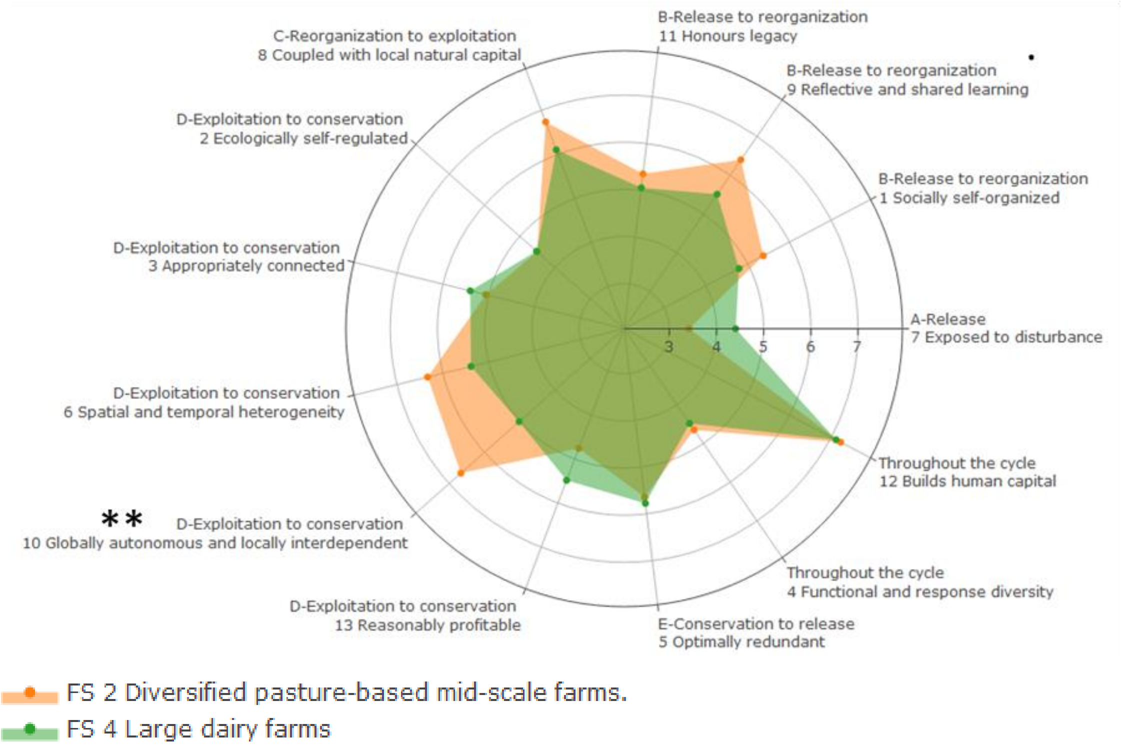
Resilience assessments

Average values for most resilience indicators differ between FS2 and FS4 but disparities within each FS complicate the analysis of significant differences. Analyses of variance were carried for each indicator, revealing only one indicator with significant different values: *10 - Globally autonomous and locally interdependent*. (see Figure 4 below). This indicates that large dairy farms (represented by FS4) are more dependent on global trends than less specialized farms (represented by FS2), which have a closer connection with their local socio-economic environment. This is particularly crucial in Switzerland where further opening of the national agri-food market to foreign production is a recurring debate, as it puts many farmers producing standard products for the food industry at risk.

As discussion workshops revealed, this risk was precisely perceived as higher than the one related to climate change. Indeed, many farmers are so far not sure about future impact of climate change on Swiss agriculture. They feel much more at risk when it comes to decrease or volatility of the prices paid for agricultural commodities.

Thus, the relative difference observed between both farming system for this indicator means a much secure situation for less specialized farmers involved in more than one supply chain and less dependent on external factors. This degree of control on their situation can also be a factor of satisfaction (Sumarwan & Hira, 1993).

Figure 28: Resilience indicators for farming systems FS 2 - Diversified pasture-based mid-size FS and FS 4 - Large dairy FS. The scoring ranges from 0 to 10 and was here zoomed from 2 to 8 to better visualize existing differences.



The general situation across the two farming systems can also be drawn from these results. We observe strengths over indicators related to learning, knowledge transmission and education (indicators 9, 11 and 12), indicating a good learning process over generations. However, the observed relative lack of positive connections among local actors may somehow prevent peer to peer learning (indicators 1, 3 and to a varying degree indicator 10).

The degree of exposure to disturbance is possibly too high in Switzerland, as shown by indicator 7. This could be due to a combination of a relatively high use of pesticides, high prices and price control for certain commodities compared to neighboring countries, and especially for Protected Designation of Origin (like Le Gruyère PDO), efficient public support in case of critical situations (for ex. severe droughts), and high level of insurance coverage. While this situation is currently comfortable, it blocks certain adaptations, as well as the learning process to adapt to shocks. Such high combination of public support and private insurance protection can be analyzed as provoking a lack of stimulation to adapt, and a less developed capacity to react to shocks when they occur. This provokes structural rigidities and anxiety by the farmers, who develop as well defensive attitudes towards changes.

Aside from the differences observed at the indicator level, the relative proximity for most indicators at the indicator level between the two FSs indicates the rather small impact of the nature and amount of the crops grown and livestock owned on the farm resilience. Elements assessed through the SHARP tool include questions about the way the land is managed and how the animals are bred (agronomic and zootechnical factors), the way production is valued and sold in and from the farm (economic factors), as well as more social factors like the education, the groups in which farmers are, etc. Thus, this study reveals that the choices made at technical level (crops, livestock) is not much correlated with the various resilience scores. The conclusion is that other communalities are more likely to play an important role, notably the agricultural policy, and the economic situation.

Based on these results, the hypothesis H1 (*The overall resilience is higher for more diversified farming systems.)* could be confirmed. However, H2 (*Diversified farming systems tend to have a stronger focus on agroecological practices while more specialised farming systems may have a stronger focus on diversifying their selling channels.)* could not be confirmed. It rather seems in this case that their high level of production in one type of output constrains them to sell to a larger intermediary processer and prevents them from reaching to other selling channels for which a diversity of production may be preferential.

Discussion workshops

Several aspects of the farm systems were discussed during the discussion workshops-The aspects discussed were: policies and standards, savings, sales prices, market access, short circuits, past collective actions, energy conservation, water conservation, ecological buffer zones, management of pests, loss of crops and livestock, associated crops and trees and agroforestry.

For each aspect discussed, the regions in which these aspects were discussed are mentioned as well as the causes and identified solutions. The ideas are reported as advanced by the participating farmers and do not necessarily reflect the views of the partners and collaborators involved in this project.

As examples, we present here the discussion of four important topics: “Policies and standards”, “Conservation of energy”, “Water conservation” and “Mixed cropping and agroforestry”.

Policies and standards were discussed in all regions: Broye, Jura, Chablais, Morges, Pays d'Enhaut. This was actually the most discussed aspect in the 5 workshops. Farmers shared their general weariness with the current system, which they believe is too restrictive and changing. The lack of consideration of local situations has also been mentioned several times, as well as the heavy administrative burden. This set makes innovative take-up difficult for most operators. The gap between the agricultural world and the rest of society and the economy has also been identified as a major fragility. Participating farmers expressed that they would like a more regionalized and stable agricultural policy. Peasant solidarity and the common defense of the rights and interests of the profession are mentioned as important elements to ensure the establishment of a satisfactory agricultural policy. Contact and communication with the rest of society are also presented as a way of freeing themselves from distorted or truncated visions of the agricultural world that are sometimes widely disseminated.

Conservation of energy was discussed in 4 regions: Chablais, Broye, Morges, Pays d'Enhaut.

The lack of energy-efficient infrastructure was notably explained by (1) the level of needed investment, (2) the sometimes heavy administrative and regulatory constraints (eg. Lavaux in the UNESCO heritage zone), (3) the lack of profitability due to the relatively too small size of farms (for example for biogas plants) and the current much too low price of energy. In order to allow for greater development of energy savings or autonomy, farmers asked for the simplification of procedures, the organization of collective networks and the promotion of small-scale solutions (such as chip boilers or old fans). Synergies between energy policy and agricultural policy should favor such a development.

Water conservation was a topic in 4 regions: Jura, Plain of the Orbe, Broye. The great variability of climatic situations between years and during each year, probably related to climate change, was found to explain the difficulty of conserving water over a year. The infrastructures were declared insufficient and often not sufficiently maintained. Increasing concreting of the landscape could also explain the instability of the water supply. Farmers advocated for more water-retaining structures to better spread water access over the year and less water-intensive farming practices such as conservation agriculture, under-seeding or the use of sheep in the vineyard to manage the grass.

Mixed cropping and agroforestry topics were discussed in three different workshops (Regions Plain of the Orbe, Morges, Nyon). The mentioned causes of a relatively weak development of these practices were (1) the level of technicality that requires time and motivation to learn, (2) the external gaze of passers-by and neighbors on visibly heterogeneous or even "dirty" plots, (3) advice provided by phytosanitary selling companies that does not always favor these practices and (4) the lack of outlets for productions resulting from these practices. For agroforestry, the participants also mentioned the complexity and the administrative rigidity, in particular at the level of zoning, as well as the need for a long-term vision to make the investment profitable over several decades, which is complicated by transmission difficulties and uncertainties at this time scale. The development of these practices therefore, according to the participants, depends on more popularization and sharing of knowledge. The participants advocated solutions to support collective agreement in order to develop adequate ways of selling the products, for ex. the establishment of agreements with mills to sort mixed crops for associated crops or self-harvesting for agroforestry. Specific material could be purchased collectively.

4. Discussion and conclusion

This study confirmed the high diversity of FSs in Canton Vaud in Switzerland. It allows a broad understanding of different farm dynamics and regional issues affecting agriculture. This diversity of productions is nevertheless tempered in terms of resilience by a rather constraining and protected context, notably due to the Swiss agricultural and commercial policies.

A limit of our approach is the small sample size per farming systems, and the scoring benchmarks used in the SHARP tool in its Swiss version, which may rather highlight all the range of possible answers instead of highlighting results when existing.

The results show that the nature of cultivated crops and the herd size (used to construct the FSs here) may not be the most relevant factors for farm system resilience, as how crops are grown and how products are sold may matter as much.

In order to understand territorial dynamics affecting farming systems and their interactions in a changing environment, there is a need for methodologies of resilience assessments suited to a diversified territory including a broad range of FSs, and not solely to specific supply chains. We believe this study paves the way forward to reach this. The greater data availability linked to the digitization of agriculture is also promising to improve the type of data collected and used for the assessment.

The SHARP approach and tool proved to be useful to reach insightful regional and farmer-based perspectives on resilience development, by evaluating individually and discussing collectively the situation and the underlying issues and opportunities. These results should however not be mistaken for sustainability assessments. Assessing resilience allows concluding on adaptation and mitigation strategies, and reasons behind adopting a proactive behavior in building more resilient FSs. Further investigation should be carried on the FS dynamics (growth, specialization, diversification, etc.) and the reasons mentioned by farmers for these changes. In our case study, this may be done in the future by further exploring farm level data over different time periods.

Although the overall context seems, from these results, to play an important role on the farm resilience, this aspect was further discussed in a meta-analysis jointly carried together with staff from the FAO by comparing our results to those of another case study in Uganda using the SHARP tool in an adapted version (Le Goff et al., 2018). This study concluded that context indeed plays a major role in resilience, with highly adverse conditions possibly favoring the use of agroecological practices and locally grounded solutions. This study further highlighted the difference existing between resilience and sustainability and the need for both approaches to support development.

In the aftermath of the project, the cantonal and federal agricultural policy responded to the concerns expressed by farmers during our discussion workshops by funding a pilot and monitored agricultural policy around agroforestry for 2020-2028 in order to better understand its actual impact in Switzerland before possibly implementing it in a future federal agricultural policy.

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ASSESSMENT OF VULNERABILITY TO CLIMATE CHANGE OF MAIZE FARMING SYSTEMS: DESIGNING AN INDICATOR SET BASED ON FARMERS' PERCEPTIONS AND KNOWLEDGE

Marine Albert, Jacques-Eric Bergez, Stéphane Couture

INRAE, France

Abstract: Maize growers in Southwestern France are facing increasing climatic variability, creating negative impacts on their farming systems (e.g soil erosion, water stress). Understanding vulnerability of these farming systems is an essential step in order to enhance new adapted farming systems toward climate change. Although vulnerability is a central concept in climate change studies (IPCC, 2021), and has already been discussed a lot in the literature (Martin et al., 2017), there is scarce knowledge on its operationalization to assess farming systems (Callo-Concha and Ewert, 2014; Urruty et al., 2016). This thesis aims at contributing to this issue by identifying determinants of vulnerability and create a generic multicriteria methodology to assess vulnerability at farm level. Surveys with maize growers are central in our work, since we build a set of indicators based on farmers' perceptions and knowledge. Original methods are used in order to elicite determinants of vulnerability, such as lottery games, role plays, and scenarii. At this stage of the thesis, results revealed (i) the important influence of cognitive and psychological factors of the farmer on vulnerability of the farming system, and (ii) a significative heterogeneity among farmers in their evaluation of adaptation strategies for reducing vulnerability. We plan to confront the set of indicators based on farmers to literature and experts in order to develop and validate the set of indicators as well as its operational framework, from a scientific point of view. To this end we will use participatory methods through focus groups involving both researchers, agronomists and technical advisors. Finally we will test the revised set of indicators with maize growers to make sure of its suitability and good handling. Results of this thesis will give knowledge and tools for advisors and policy-makers to adapt their support strategies for maize growers, in a context of climate change.

CAN WE PUSH AGROECOLOGY A STEP FURTHER?

Sara BURBI[a], Ulrich SCHMUTZ[b] and Stéphane BELLON[c]

[a] Centre for Agroecology, Water and Resilience (CAWR), Coventry University, United Kingdom
[b] Centre for Agroecology, Water and Resilience (CAWR), Coventry University, United Kingdom
[c] French National Institute for Agricultural Research (INRA), Department of Sciences for Action and Development, Avignon, France

Abstract: There have been many studies recently advocating for the adoption of more agroecological farming practices related to climate change. In this session we want to go beyond the initial concepts of agroecology and address specific needs such as reduced dependence on external inputs. We feel, while agroecology can be well received as a theoretical concept by practitioners in a wide range of contexts, there is a need to delve deeper into its practical and technological aspects to implementing it further. We are looking for works that takes agroecology a step further. For example, farming system solutions for Mediterranean horticulture with zero pesticides inputs (also including zero copper or mineral oils - still allowed in certified organic farming) can be a challenge to implement and may need innovative approaches. Another example can be silvopastoral systems the production of tree fodder with anti-parasitic and anti-microbial effects, eliminating synthetic drugs use in animal husbandry. Similarly, the use of plastics is still wide-spread and phasing out other climate change relevant inputs like peat has still not taken off, especially in horticulture. Food storage and processing can also be an asset in alleviating impacts of climate change. Moreover, technological pathways exemplifying how changed agroecological food and farming systems can contribute to climate-friendly designs are welcome. These may include a reduction in use of external inputs during the production phase, dietary changes and pasture management strategies to reduce emissions from livestock, storage, treatment and application technologies to mitigate emissions from manure. The potential consequences of changed practices and inputs on the adaptation and mitigation of climate change are important to assess, together with their integration into short food supply chains and changed diets.

CARBON FOOTPRINT OF IBERIAN DEHESA PRODUCTS: SEQUESTRATION IN SOILS AND WOODY VEGETATION CAN OFFSET LIVESTOCK EMISSIONS.

Mireia Llorente[a], Gerardo Moreno[b]

[a] Forestry School, University of Extremadura, Plasencia, Spain
[b] INDEHESA, Forestry School, University of Extremadura, Spain

Abstract

The Iberian dehesa is a traditional, but also up-to-date, Mediterranean agrosilvopastoral system. It might be regarded as a successful example of how a farming system can be compatible with resource conservation and sustainable development, while also playing an interesting role in Climate Change mitigation. Carbon from the atmosphere is fixed by plant photosynthesis and stored as carbon in aboveground and belowground biomass. Soil organic matter also represents a great sink of C. In parallel, greenhouse gas emissions from livestock production systems are usually considered to be the largest source of agricultural emissions. There is a knowledge gap regarding to what extent carbon sequestration in the ecosystem can offset emissions in extensive silvopastoral systems. The link between Climate Change and livestock farming has made the Carbon Footprint a worldwide indicator for assessing and communicating the amount of greenhouse gases emitted per unit of product. Nevertheless, most studies do not include soil and biomass carbon sequestration in their carbon footprint calculations. In this study, we point out the importance of noting that extensive farming is closely linked to dehesa ecosystem conservation and, therefore, the carbon footprint in pastoral systems should take geographical location into account.

We measured soil C stock changes at 110 points of the Iberian dehesa over a mean period of 22 years. We found temporal changes in soil C concentration ranging from -0.055 to 0.199% per year, with a SOC stock change average of 0.83 $Tn{\cdot}ha^{-1}{\cdot}year^{-1}$. That amount represents an annual soil C stock growth rate of around 11‰, way above the proposed '4 per mille Soils for Food Security and Climate' of the Lima-Paris Action Agenda. Aboveground biomass stock changes of trees were also measured by comparing the Spanish National Forest Inventories. The C sequestration rate in the trees amounts to 0.08 Ton $C{\cdot}ha^{-1}{\cdot}year^{-1}$. Taking into account soils and vegetation, C sequestration in dehesas would offset most of the emissions of GHG estimated for the livestock-based food produced in the pastoral farming system, including on- and off-farm emissions.

INTRODUCTION

Dehesas are agroforestry systems characterized by scattered trees among pastures, crops and/or fallows. Dehesas are traditional, but also up-to-date, agrosilvopastoral ecosystems of the Iberian Peninsula, which are adapted to the unpredictability of the Mediterranean climate (Joffre et al. 1999; Moreno and Cubera 2008). These multipurpose systems cover at least 4 million hectares in central and south-western Spain (Moreno and Pulido 2008). Extensive livestock systems are largely responsible for the ecological features of the dehesa. Livestock take advantage of the forage resources, not just comprising grassland, but also trees, which are used, not only as a resource in their own right, but also as a regulator of hydrological stress for the underlying herbaceous stratum (Joffre et al., 1999). Thanks to a reduced stocking rate, a balance can be achieved between animal pressure and the conservation of the territory.

The significant contribution of food production to greenhouse gas (GHG) emissions (Herrero et al., 2013) has made calculating the Carbon Footprint (CF) of food products increasingly popular. In that sense, it is important to note that extensive farming is closely linked to ecosystem conservation and, therefore, the CF in agroforestry systems should take geographical location into account. Carbon sequestration (C) in agroforestry systems must slow or even reverse the increase in atmospheric concentration of CO_2 by storing soil organic carbon (SOC) for millennia (Lorenz and Lal, 2014; Waldrom et al., 2017). However, there is a knowledge gap regarding to what extent C sequestration in the ecosystem can offset emissions in extensive silvopastoral systems, and usually no - or only generic - information on C sequestration rates is included in CF calculations.

Agroforestry systems are able to store significant quantities of C in biomass and soils. On the one hand, the largest terrestrial pool of C is found in soils, with spatially variable but large annual C exchanges with the atmosphere. Moreover, SOC is the major determinant of soil quality, and it greatly influences the global carbon cycle and climate change. Restoring, increasing and protecting SOC is, therefore, a global priority and is covered by the United Nations Conventions on Climate Change, Desertification and Biodiversity (Cowie et al., 2011). The SOC pool, in particular, is the only terrestrial pool with the ability to store carbon for millennia, and that ability can be deliberately enhanced by agroforestry practices (Lorenz and Lal, 2014). Therefore, dehesas would play an important role in the mitigation of global climate change through soil and vegetation conservation and management. However, the spatial heterogeneity of dehesas, their complex management and their generally low soil organic carbon contents (Howlett et al., 2011; Rodeghiero et al., 2011) may be the reason for the scant attention paid to that ecosystem. Determining the C storage capacity of this expansive land use in Spain will be vital to national C accounting, and may serve to foment the restoration of this and other savanna-like systems in the world.

On the other hand, vegetation C stocks and sequestration rates are both an important compartment in the C cycle and a relevant factor in soil C stocks, although the incorporation of biomass vegetation C stock and its C sequestration rates into CF of agroforestry products is scarce (Ruiz-Peinado et al., 2013). The rate of tree growth and timber harvesting determines the C storage capacity of living biomass and deadwood. Data from the Second and Third Spanish National Forest Inventories, which reflect changes over 10 years, is a useful tool for estimating the C storage in the tree biomass of dehesa systems and also the change rate in the C stock. The belowground biomass of forest landscapes plays a key role in carbon storage (Litton and Giardina, 2008). Since estimating belowground biomass is a complex process which requires great effort in terms of the time and cost of collecting data, a plausible approach to investigating forest belowground biomass is to establish a relationship between a number of dendrometric parameters related to the aboveground vegetation (e.g., tree diameter and height) and the belowground component of the total biomass (Ruiz-Peinado et al., 2012).

This study was undertaken to: (1) quantify C stocks in soils and tree biomass of Iberian dehesa systems; (2) estimate the C sequestration rate of the ecosystem by calculating C stock change rate; (3) establish the C sequestration potential of the dehesa following the concept of C saturation and soil C saturation deficit; (4) balance the C sequestration capacity of the dehesa and GHG with its extensive livestock systems.

MATERIAL AND METHODS

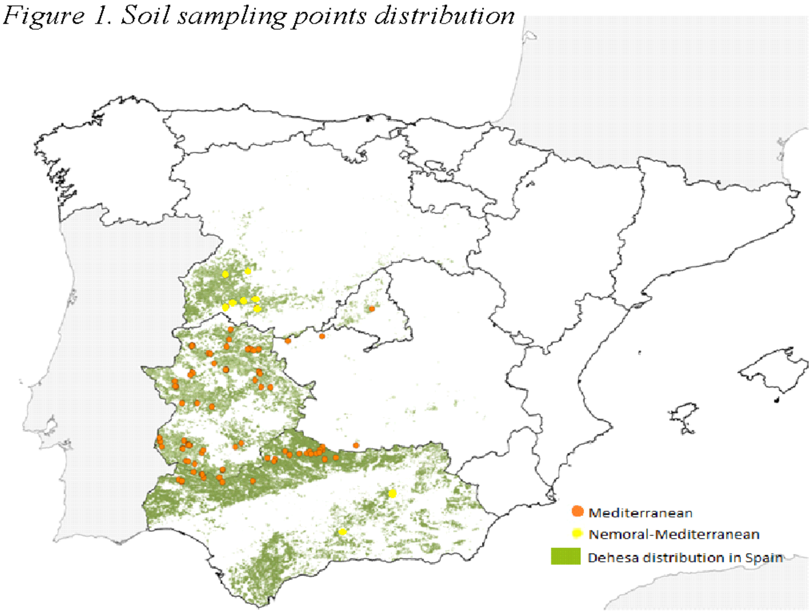
Site Description

The Mediterranean dehesas are between 350 and 550 m.a.s.l. The climate is typically Mediterranean, with high climatic intra- and inter-annual variability. Rainfall, from 400 to 800 mm, is concentrated during the cooler months of the year and there is a long period of summer drought, with high temperatures and without relevant rainfall. The mean annual temperature ranges from 14 to 17ºC. During periods of dry and sunny weather, between June and September, plant-available water is quickly exhausted. Characterized by the presence of a savannah-like open tree layer, mainly dominated by Mediterranean evergreen oaks – holm oak (*Quercus ilex*) and cork oak (*Q. suber*) – and to a lesser extent by the deciduous *Q. pyrenaica* and *Q. Faginea,* dehesas are usually found on acid soils originating from siliceous, which is poor in nutrients and has shallow soils (rarely > 50 cm). This low fertility has limited its use for growing crops. Soil variability is high in the dehesas as a result of erosion, transportation and sedimentation processes from hillsides and seasonal streams. The soil is mostly luvisols, leptosols and cambisols with different depths and development.

Selection of Dehesa Soil Data

A large number of collections of available published data from different soil surveys of Spanish dehesa systems were consulted. Finally, we selected information on 110 dehesa stands previously published in three main soil databases: 55 geopoints were extracted from Pulido-Fernández et al. (2015); 26 geopoints belonging to the soil database generated in the framework of the ICP-Forest Programme (International Cooperation Programmes) and published by Moreno and López-Arias (1997); 30 geopoints belonging to the soil database generated in the framework of the Red CARBOSOL Project and published by Llorente et al. (2018). The point selection criteria in the literature were 1) georeferenced profiles of at least 30 cm depth (separated in 0-5, 5-10 and 10-30 cm); 2) description of soils' physico-chemical characteristics (bulk density, pH, soil texture fractions, N, CEC, K, Mg, Ca); 3) sampling date at least 10 years prior to our sampling year (2018). The sampling points were well distributed throughout the Iberian dehesa region (Fig. 1) and ranged from 1959 to 2006.

Figure 1. Soil sampling points distribution



Soil Sampling and Analysis

The soil sampling methodology was followed according to the ICP Forests Manual (Cools & De Vos, 2016). Quadrupled samples of soil, till 30 cm depth, were extracted in each selected geopoint. Separated subsamples of 0-5, 5-10 and 10-30 cm depth were dried, sieved (< 2mm) and stored in plastic bags. Milled samples were analyzed for C and N by a LECO C.N.H.S. Elemental Analyzer (Model CHNS-932, LECO Corporation, St Joseph, Michigan, USA).

Soil Carbon Stocks and Their Change Rates Calculation

SOC stock (SOC_{stock}) per unit area (Ton of C $\cdot ha^{-1}$) was estimated according to Eq. 1:

$$SOC_{stock} = SOC * BD * T \quad (1)$$

Where SOC is the C concentration in the soil sample, BD is bulk density (g cm^{-3}) and T is layer thickness (30 cm, according to EU directive).

The SOC_{stock} change rate (ΔSOC_{stock}) per unit area and time (Ton of C $\cdot ha^{-1} \cdot year^{-1}$), equivalent to the C sequestration rate, was estimated according to Eq. 2:

$$\Delta SOC_{stock} = (SOC_{stock\_t2} - SOC_{stock\_t1}) / (t_2 - t_1) \quad (2)$$

Where SOC_{stock} is the SOC stock per unit, t_1 is the year of first sampling and t_2 is the year of second sampling.

Forest Inventory Data Management

We selected information from the Second Spanish Forest Inventory (IFN2) and Third Spanish Forest Inventory (IFN3) from Extremadura, Andalucía, Castilla la Mancha and Castilla León regions. IFN2 was conducted for those regions between 1990 and 1996, while IFN3 was conducted between 2000 and 2008. In this study, we selected 3,823 dehesa plots following the criteria: a) points that were sampled in both IFN2 and IFN3; b) main tree species (>50%) represented by *Quercus sp*. or *Olea europaea*; c) forest density of below 80 trees$\cdot ha^{-1}$. Criteria b) and c) were established following the definition of dehesa systems of Pulido and Picardo (2010). IFNs comparison and management was done using Basifor 2.0 software (Bravo et al., 2001).

In both surveys, forest plots were divided into four nested circular subplots (with a radius of 5, 10, 15 and 25 m); and trees were recorded only if their diameter was larger than a certain threshold (7.5, 12.5, 22.5 and 42.5, respectively). Species identity, height and diameter at breast height (d.b.h.) of living and standing dead trees were available for both surveys. On a circular plot with a 5 m radius, the number of saplings per species (2.5 cm ≤d.b.h. < 7.5 cm) and their mean height was also recorded. Species identity, canopy cover and mean height of woody understory vegetation was sampled within the 10-m radius plot.

Tree Biomass Carbon Stocks and Their Change Rate Calculation

Structural measurements of IFN2 and IFN3 for all 3,823 selected plots were converted to biomass carbon densities by using allometric equations. IPCC (2006) guide equations for above and belowground tree biomass was used, however specific Biomass Expansion Factor (BEF), Root-to-Shoot Ratio (R), and Carbon Fraction (CF) for each species were used when available in the Montero et al. (2005) database.

Tree biomass stock (including above and belowground) per unit of area (Ton of dry matter $\cdot ha^{-1}$) was estimated according to Eq. 3:

$$Bha = VOB*BEF*(1+R) \quad (3)$$

Where VOB is volume over bark (m^3 ha^{-1}), BEF is the biomass expansion factor and R is the ratio of aboveground oven-dry biomass of tree to belowground oven-dry biomass.

C biomass stock (including above and belowground) per unit of area (Ton of C $\cdot ha^{-1}$) was estimated according to Eq. 4:

CB = Bha*CF (4)

Where CF is the specific C fraction for each species.

The CB change rate (ΔCB) per unit area and time (Ton of C $\cdot ha^{-1} \cdot year^{-1}$), equivalent to the C sequestration rate, was estimated according to Eq. 5:

$\Delta CB = (CB_{t2} - CB_{t2}) / (t_2 - t_1)$ (5)

Where CB is the C biomass stock per unit area, t_1 is the year reported in IFN2 and t_2 is the year reported in IFN3.

Statistical Analysis

Analysis of variance (ANOVA) was used to compare variables. In case of significant F-statistics ($p>0.05$), differences between means were tested with the Tukey procedure for multiple comparisons. Data were tested for normality and homoscedasticity with the Kolmogorov-Smirnov and Levene's statistics respectively. The statistical analyses were carried out using R software (R Core Team, 2017).

RESULTS AND DISCUSSION

Soil C Stocks and Soil C Sequestration Rate of Iberian Dehesa Systems

Most soil samples corresponded with Haplic Cambisols (96%) and several others to Haplic Luvisols. The main physical and chemical properties of soils sampled throughout the dehesa ecosystem are displayed in Table 1.

Table 1. Characteristics of Dehesa Soils in Spain.

Soil property	Mean ± sd	Max	Min
Clay (%)	11.8 ± 7.7	30.0	2.6
Bulk Density. ($g \cdot cm^{-3}$)	1.45 ± 0.15	1.74	1.08
pH (aq)	5.61 ± 0.77	7.84	4.21
CEC ($cmol \cdot kg^{-1}$)	10.1 ± 5.9	24.5	3.6
Ca (ppm)	1011 ± 514	2400	220
Mg (ppm)	255 ± 162	1305	37
K (ppm)	125 ± 123	821	22
Na (ppm)	70 ± 32	276	23
N ($g \cdot kg^{-1}$)	1.52 ± 1.08	6.30	0.40

Data refer to mean and standard deviation (sd) values of the 110 soil samples.

C sequestration can be defined as the uptake of C-containing substances and, in particular, CO_2 into another reservoir with a longer residence time (IPCC, 2007). Ideally, SOC sequestration should be reported as rates (in mass SOC per unit of area and time). However, SOC sequestration data are mostly reported as pools or stocks. We know that some SOC in agroforestry systems may persist for millennia, indicating that terrestrial sequestration for climate change mitigation occurs particularly by avoiding net SOC losses and the slowly ongoing accumulation of the slowest SOC pool (Mbow et al., 2014; Schmidt et al., 2011). In our study we found that the dehesa system ad an annual growth rate of soil C stock of around 11‰, greatly above the proposed '4 per mille Soils for Food Security and Climate' of the Lima-Paris Action Agenda. The aim of using dehesa systems for climate change mitigation purposes should be to reduce SOC losses and enhance SOC stabilization. It should be mentioned that in the past few decades, the degradation of the dehesa system by land use change, lack of tree regeneration and disease (particularly, the root caused by the pathogen *Phytophthora cinnamomi*) has threatened to undermine the potential secondary environmental benefits provided by these systems. Agroforestry systems have higher C stocks in aboveground biomass as compared with treeless pastures, or natural grasslands (Nair et al., 2014), and there is also evidence that C storage in deep soil horizons is greater in a number of AF systems (Lorenz and Lal, 2014). Therefore, the Kyoto Protocol recognized AF systems as a strategy for soil carbon sequestration (IPCC, 2006).

The current mean stock of C in soils (0-30 cm depth) of the Iberian dehesa is 72.0 Ton of C $\cdot ha^{-1}$ with great variability between sites, ranging from 25.3 to 149.9 Ton of C $\cdot ha^{-1}$. For the same soil profile depth, we found a SOC concentration average growth rate of 0.20 g $C \cdot kg^{-1} \cdot year^{-1}$ (ranging from -0.62 to 1.61 g $C \cdot kg^{-1} \cdot year^{-1}$), corresponding to a SOC sequestration rate average of 0.83 Ton of $C \cdot ha^{-1} \cdot year^{-1}$ (ranging from -2.51 to 5.57 Ton of $C \cdot ha^{-1} \cdot year^{-1}$). In addition, we found, for an average interval of 22 years, that the mean content of soil C increased from 1.35 to 1.66%, which translates into a mean accumulation in the uppermost 30 cm of the soil equivalent to 0.83 $Ton \cdot ha^{-1} \cdot year^{-1}$. The same change patterns were found for the 0 to 5 cm soil profile interval as is shown in Table 2, although more intensity of C sequestration for that depth interval was estimated, with a SOC concentration average growth rate of 0.28 g $C \cdot kg^{-1} \cdot year^{-1}$ (ranging from -1.00 to 2.70 g $C \cdot kg^{-1} \cdot year^{-1}$).

Table 2. Soil C Density, Stocks and Sequestration Rate.

Soil property	X_{t1} (mean ± sd)	X_{t2} (mean ± sd)	X_{t2} - X_{t1}	(X_{t2} - X_{t1}) /(t2-t1)
Year	1996 ± 13.0	2018 ± 0.0	22.11 ± 13.0	1.00 ± 0.0
%OC (0-5 cm)	1.51 ± 0.81	1.83 ± 1.19	0.31 ± 0.95	0.02 ± 0.05
%OC (0-30 cm)	1.35 ± 0.57	1.66 ± 0.63	0.31 ± 0.61	0.02 ± 0.04
SOC_{stock} (0-5 cm)	13.43 ± 6.12	15.67 ± 8.00	2.24 ± 7.56	0.15 ± 0.44
SOC_{stock} (0-30 cm)	58.70 ± 25.21	72.02 ± 26.55	13.32 ± 26.19	0.83 ± 1.55

Data refer to mean and standard deviation (sd) values of the 110 soil samples. SOC_{stock} expressed in Ton of C $\cdot ha^{-1}$ and t_n in years.

C sequestration in soils varies widely depending on the agroforestry system, but, given the same climatic and edaphological conditions, usually agroforestry systems have more C sequestration capacity than tree plantations or crops (Nair et al., 2009). Studies on SOC sequestration rates in AF systems report rates from -0.39 Ton $C \cdot ha^{-1} \cdot year^{-1}$ for cacao+canopy trees in agroforestry in Ghana (Isaac et al., 2005) to 4.16 $C \cdot ha^{-1} \cdot year^{-1}$, as reported by Beer et al (1990) for cacao+*Erythrina poeppigiana,* in Costa Rica's agroforest system. Oelbermann et al. (2006) indicated that although tropical agroforestry systems may have higher SOC sequestration rates, temperate systems may be more effective in soil stabilization because of the residue C inputs from tree prunings, litterfall, and crop residues. Native soil C levels reflect the balance of C inputs and C losses under native conditions, but do not necessarily represent an upper limit in soil C stocks. Empirical evidence demonstrates that C levels in intensively managed agricultural and pastoral ecosystems can exceed those under native conditions. Greater soil C stocks directly underneath the tree canopy suggest that maintaining or increasing tree cover, may increase long term storage of soil C in dehesa silvopastoral systems. The processes contributing to sequestration rates and the stabilization of SOC in agroforestry soils need additional data and research.

Soil C Saturation Level and C Sequestration Potential.

Most current models of SOM dynamics assume first-order kinetics for the decomposition of various conceptual pools of organic matter, which means that equilibrium C stocks are linearly proportional to C inputs (Paustian et al., 2007). These models predict that soil C stocks can, in theory, be increased without limit, without the assumptions of soil C saturation. However, especially for soils with low to moderate C levels (e.g. <5%), there is evidence of a carbon saturation level (Solberg et al., 1997). There are several lines of evidence that suggest the existence of a C saturation level based on physicochemical processes that stabilize or protect organic compounds in soils. The soil C saturation concept suggests that with increasing C inputs, the SOC stock will reach a maximum, and the SOC accumulation rate will decrease during this process (Six et al., 2002). The difference between the saturated organic C content in the fine fractions and the actual measured organic C content of these fractions is referred to as the stable soil C saturation deficit (Six et al., 2002). This soil C saturation deficit affects the ability of soils to store C inputs in a stable form and indicates the potential of a soil for sequestering C. Nevertheless, C may accumulate beyond the hypothetical soil C saturation threshold. Plants producing low-quality FOC (fresh organic carbon) can promote soil C sequestration beyond the hypothetical saturation threshold. The saturation concept is only applicable to SOC stabilized by microbial activity, while the particulate-recalcitrant C would continue to increase beyond the saturation level (Castellano, 2015).

In accordance with the soil C saturation concept, we found a significant decrease (Slope= -0.022; R^2= 0.292; p <0.001) in the SOC change rate related to the initial SOC concentration (*Fig 2*), which indicates greater sequestration rates in originally poorer soils. Fitting a model following this SOC saturation concept allowed for an estimation of the average soil C storage potential of around 2.8%, way above the current 1.7% mean content. We found a theoretical SOC storage capability of around 1.1%, which differed greatly to the current average content, indicating a great future potential for storing C in dehesa soils.

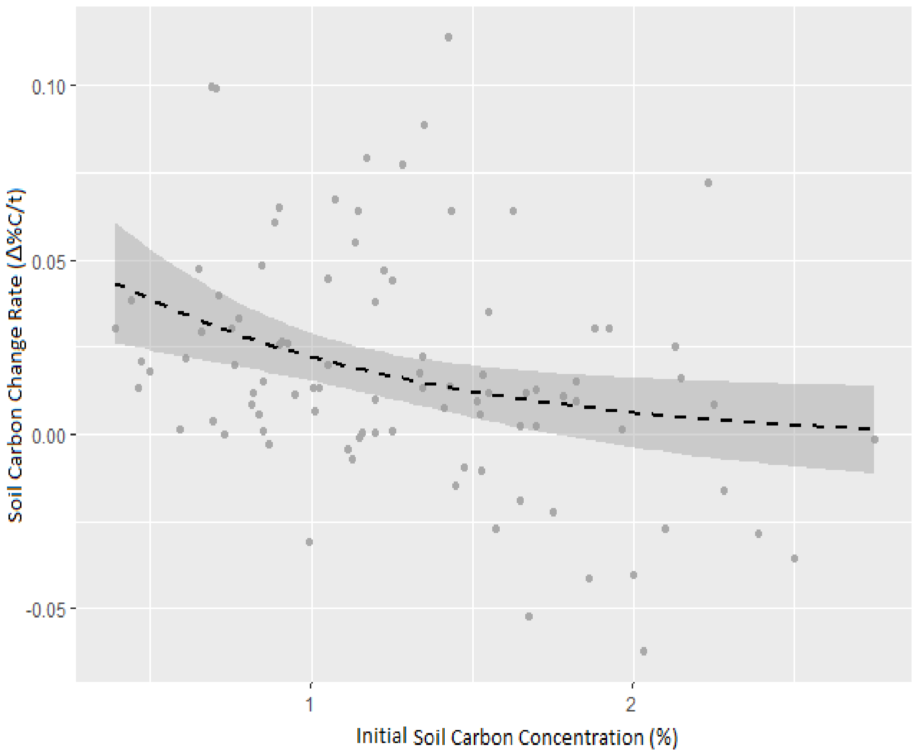


Figure 2. Soil Carbon change ratio with respect to the initial soil carbon concentration

Tree Biomass C Stocks and Changes

A total of 3,823 plots were selected from both IFNs. *Quercus ilex* was the dominant tree species in the majority of the dehesa plots (88.6%), followed by *Quercus suber* (5.4%) and *Quercus pyrenaica* (4.9%). We rarely found dehesa systems dominated by *Quercus faginea* or *Olea europaea*. Average tree structure characteristics of both IFNs and their comparison are shown in Table 3.

The current mean C stock in tree biomass of dehesa systems is 8.05 Ton of C $\cdot ha^{-1}$, with great variability between sites, ranging from 1.13 to 30.82 Ton of C $\cdot ha^{-1}$. The mean C sequestration rate of trees in dehesa systems amounted to 0.078 ± 0.19 Ton of C$\cdot ha^{-1}\cdot year^{-1}$, with this rate of change ranging from -3.03 and 1.30 Ton of C$\cdot ha^{-1}\cdot year^{-1}$. As is shown in Figure 3, increases in tree biomass C stocks tended to be greater in those plots with lower biomass C stocks at IFN2.

Table 3. Iberian Dehesa Tree Biomass Characteristics

	IFN2	IFN3	ΔIFN3-IFN2
Year	1991 ± 1.7	2002 ± 1.9	10.84 ± 0.6
Tree number (indiv$\cdot ha^{-1}$)	35.1 ± 18.7	35.3 ± 18.7	0.11 ± 10.0
d.b.h. (cm)	4.5 ± 2.4	4.9 ± 2.5	0.38 ± 1.0
Total Height (cm)	6.5 ± 1.5	7.5 ± 1.6	0.59 ± 1.1

VOB ($m^3 \cdot ha^{-1}$)	8.96 ± 5.19	10.02 ± 5.59	1.06 ± 2.67
Tree biomass stock* ($Ton \cdot ha^{-1}$)	15.15 ± 8.81	16.96 ± 9.46	1.80 ± 4.47
C biomass (Ton of $C \cdot ha^{-1}$)	7.19 ± 4.18	8.05 ± 4.49	0.86 ± 2.12

**Tree biomass stock is expressed as oven dry matter*

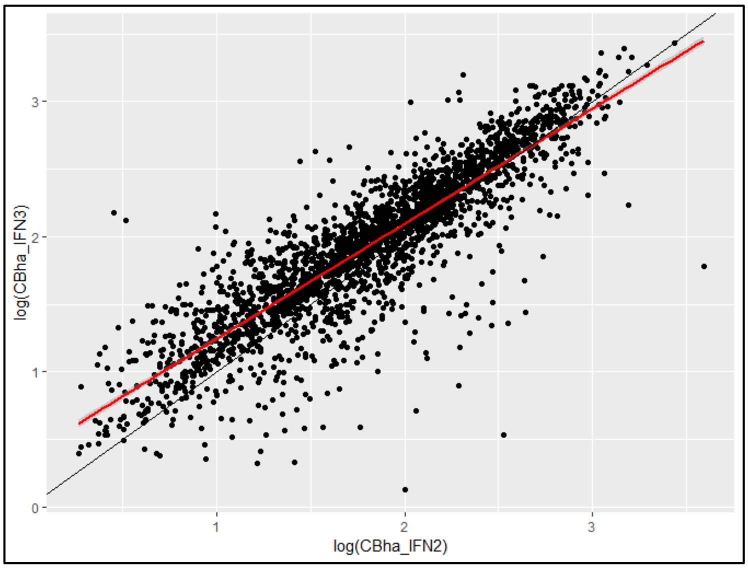


Figure.3. Biomass tree Carbon comparison IFN2 vs. IFN3. Logarithmic transformation of variables is represented.

C sequestration occurs in trees in dehesa systems, both in belowground biomass (i.e., branch, foliage or stem) and aboveground biomass (i.e. roots, and rhizosphere). Aboveground, the tree root-derived C inputs are a great source for the SOC pool in deeper horizons (Kell, 2012). In parallel, tree roots have the potential to recover nutrients from below the crop rooting zone, resulting in an enhancement of tree and crop growth by subsequent increase in nitrogen nutrition, which may result in an increase in SOC sequestration (Van Noordwijk et al., 1996). Belowground, trees modify the quality and quantity of litter C inputs and modify microclimatic conditions such as soil moisture and temperature regimes (Laganière et al., 2010).

Comparing tree biomass C stocks in each plot, grouping data by dominant tree species, we found significant differences between the groups (F-value= 8.280, $p<0.001$). A Tukey post-hoc test indicated that those plots dominated by *Q.ilex and Q.suber* had significantly greater biomass C stocks than those dominated by *Q.pyrenaica* ($p<0.001$). Significant differences ($p<0.01$) were also found between plots dominated by *Q.ilex* and those dominated by *Q.suber* with a greater average C stock for *Q.suber* systems (Fig 4.). The comparison of biomass C sequestration rates, grouping by dominant tree species, also shows differences by group (F-value= 5.231, $p<0.001$). A Tukey post-hoc test revealed the same data behaviour as for C biomass stocks, with significantly greater C stock sequestration rates for dehesas dominated by *Q.ilex* and *Q.suber* than those dominated by *Q.pyrenaica,* and higher rates for dehesas dominated by *Q.suber* than those dominated by *Q.ilex* (Fig 4.).

It has been argued that old forests are unimportant in addressing the climate change problem because carbon offset investments focus on planting young trees, as their rapid growth provides a higher sink capacity than old trees. Recent research findings have demonstrated that old-growth forests are likely to function as carbon sinks (Luyssaert et al., 2008). The considerable length of time it takes new plantings to sequester and store the amount of carbon equivalent to that stored in mature forests counters the argument regarding the rapid growth of young trees. In that sense, it is useful to distinguish between the carbon carrying capacity of an ecosystem and its current carbon stock. Carbon carrying capacity is the mass of carbon able to be stored in a tree-dominated ecosystem under prevailing environmental conditions. It is a landscape-wide metric that provides a baseline against which current carbon can be compared. The difference between carbon carrying capacity and current carbon stock allows an estimate of the carbon sequestration potential of an ecosystem.

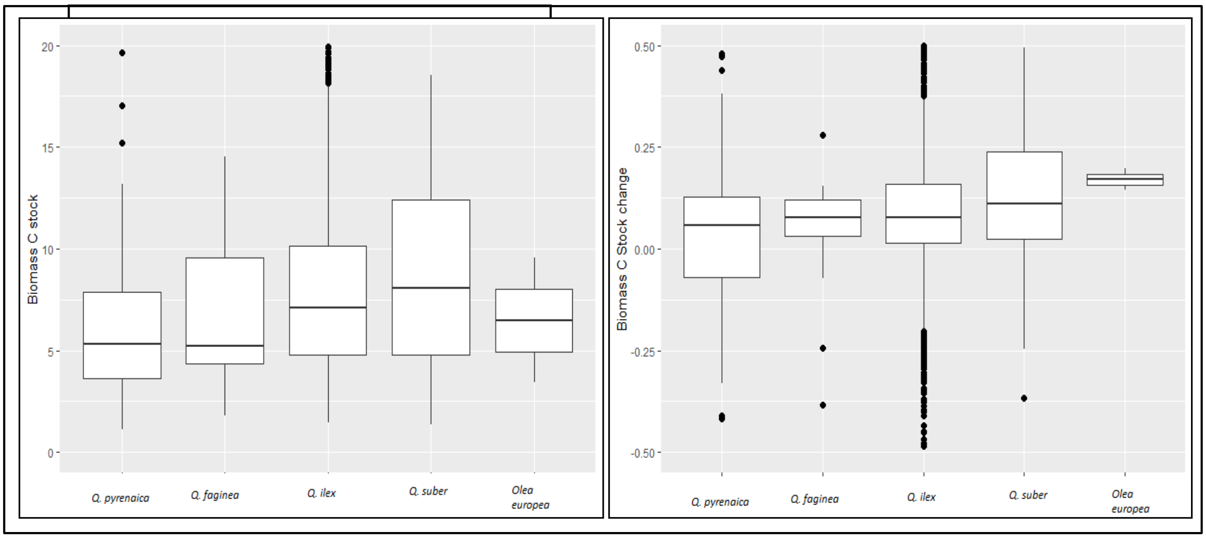


Figure.4. Boxplot of the tree biomass C stock (Ton of C·ha^{-1}) and tree biomass C sequestration rate (Ton of C ·ha^{-1}·year^{-1}) represented by dominant tree species in the dehesa plot.

Towards Neutral Carbon Farming Systems

There is a potential to sequester C in soil and tree biomass by conservation and good management practices of dehesa systems. The livestock sector, globally, represents 12% of all human GHG emissions (Havlik et al., 2014). However, it is important to distinguish livestock farming systems when we are trying to assess animal production's climate responsibility. Pastoral systems are closely linked to the conservation of dehesa systems and grasslands, and soil CO_2 sequestration in grasslands has a great mitigation potential (Crosson et al., 2011). We argue that pastoral-based production systems come close to representing a carbon-neutral emissions production method.

Specifically, our study on GHG sink and source balance in dehesa systems indicates that extensive livestock systems linked to dehesa system conservation comes close to being zero-emission production. The C sequestration capacity of dehesa soils was estimated at 0.827 Ton of C·ha^{-1}·year^{-1} (0-30 cm), while the C sequestration in the trees amounts to an equivalent of 0.078 Ton of C·ha^{-1}·year^{-1}. In summary, soils and tree biomass together add up to an average sink of 0.905 Ton of C·ha^{-1}·year^{-1}. This C sequestration rate would offset most of the emissions of GHG estimated for the extensive livestock farming systems produced in the dehesa. Eldesouky et al. (2018) have estimated emissions of 1.066 Ton of C·ha^{-1}·year^{-1} for extensive beef farms and of 1.319 Ton of C·ha^{-1}·year^{-1} for the extensive meat sheep farms, including on- and off-farm emissions. Taking into account that the 3rd quartile of soil C and tree biomass C sequestration rates estimated in our study were 1.461 Ton of C·ha^{-1}·year^{-1} and 0.161 Ton of C·ha^{-1}·year^{-1}, respectively, we can suppose that an improvement in the management of the soil and vegetation of dehesa systems could increase the current C sequestration rate of farms located within these systems.

From here we can conclude that, currently, C sequestration in soil and trees of the Iberian dehesa offsets most of the GHG emissions associated to extensive livestock production systems, and even has the potential to sequestrate more C than these systems emit, making it a net sink GHG food production system. These results provide clear indications of the possibilities for climate change mitigation and even opportunities for economic benefit through carbon trading. Therefore, managing carbon flows in agroforestry ecosystems more efficiently is central to limiting climate change. It is important to note that processes contributing to sequestration rates and the stabilization of SOC in agroforestry soils need additional data and research.

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HORTICULTURAL AGROFORESTRY: THE CHALLENGE OF DIVERSIFICATION SERVICES

Tchamitchian, Marc, Alfonzo-López, Dayaleth, Raphaël Paut, Rodolphe Sabatier, Romain Roche

INRA, ECODEVELOPPEMENT, France

Abstract: Agriculture specialization and intensification has led to a biodiversity loss in while this biodiversity fulfils several services in agroecosystems, among which natural regulations and pest control. Cropping system diversification is a promising answer to these challenges, in the frame of agroecological transitions of agriculture. In this context, agroforestry combines diversification with other potential services, densification of the production, synergies between crops, enhancing natural regulations, and seems a very promising opportunity. Following this line, horticultural agroforestry, mixing fruit trees and vegetable crops on the same plot is gaining momentum as a strategy to address both the consumer demand and these ecological goals. These systems embed a high biological diversity, through the association of several crops at the same on time on the same plot, and through the large number of crops in rotation along time.

However, recent works points out that some of those services are not so favorable as hypothesized. For example, a positive link between the increase of the number of crops and the number of different enemies has been shown, with consequences on the damages to the crops, also increasing with the number of different crops. On the contrary, production variability has been shown to decrease while diversification increases, at the expanse of the total productivity, unless synergies between crops are exploited (associating crops with Land Equivalent Ratios larger than one). It appears therefore that the diversification has contrasted effects, making the evaluation of its benefits a real challenge.

In this presentation we will propose a framework to guide the evaluation of the balance between these different services, in relation to the structure and the composition of the horticultural agroforestry system at hand. This framework would therefore allow to support the design of such systems, in terms of complexity and in terms of organization.

RETRO-INNOVATION AS A TOOL TO ADDRESS KEY ENVIRONMENTAL CHALLENGES – THE CASE OF ACORN CONSUMPTION IN PORTUGAL

Ana Margarida Fonseca[a], Teresa Pinto-Correia[b], Ana Cristina Agulheiro[c], Filipa Cachapa[d]

[a] Instituto de Ciências Agrárias e Ambientais Mediterrânicas
[b] Instituto de Ciências Agrárias e Ambientais Mediterrânicas
[c] Instituto de Ciências Agrárias e Ambientais Mediterrânicas
[d] Instituto de Ciências Sociais da Universidade de Lisboa

Abstract:

There has been a growing interest in using old products which have represented important resources in the past but the growing urbanization of lifestyles has led to oblivion. Although these products and linked practices are far from the current market economy that make intensive use of energy and other inputs, they can represent a contribution to deal with the major environmental and social challenges we face today. Acorns represent an important production of Portuguese forest. Although being nowadays used mainly as livestock feed, acorns were used directly as part of the human diet for centuries. Its consumption decreased due to the progressive improvement in living conditions of the rural population and the influence of the urban culture in the countryside. In recent years, the use of acorns has been re-introduced as niche activities, by some agri-food companies, interested in diversifying the sources of income. The number of companies exploring the acorn as well as the number of acorn-based products were also been growing, initially more inspired by recipes used in the past and, more recently, with a higher degree of technology incorporation. We propose to explore these retro-innovations as a way to contribute to maintain acorns producing systems, without compromising them, and we will dwell on its potential as a tool to responding to present and future challenges related with climatic change, the need for decarbonising the economy, to overcome the nutritional impoverishment of our menus and to explore new ways of managing resources.

1. Introduction:

In Portugal acorns can come from two main systems, the deciduous oaks forests distributed roughly in the north of the country and managed as silvo-pastoral systems with extensive grazing or denser forested areas exploited for timber (Acácio et. Al. 2017) and the *Montados*, a silvo-pastoral system which spreads mainly in the south. In the northern oak forests, the main oaks species found are *Quercus robur*, *Quercus faginea* and *Quercus pyrenaica* (ICNF, 2016). In the southern *Montados*, the acorns are produced mainly by *Quercus rotundifolia* (holm oak) and *Quercus suber* (cork oak) (Bingre et al., 2007; Acácio et al., 2017). In the northern oaks' forests, goats can use several resources as shrubs and trees leaves and branches (Castro et al., 2017). In the *Montado* system tree canopy coexists with natural pastures and some shrubs with the main intent of cattle production (Pinto-Correia et al., 2011; Sá Sousa, 2014). In *Montado* livestock rearing is the major source of income in areas where holm oaks dominate (areas with higher continentality index) and cork income dominates in cork oak areas (areas with greater Atlantic influence). Both northern oaks forests and Montados are generally recognised as sustainable systems (Pinto-Correia et al., 2011; Mosquera-Losada, 2012; Castro et al. 2009) being, the first, a 2000 Natura Site "Carvalhais Galaico-portugueses de *Quercus robur* e *Quercus pyrenaica* – Nº 9230" from Habitats Directive (Council Directive 92/43/EEC of 21 May 1992), and the later recognised as high natural value systems at a European level (Almeida et al., 2013; Pinto-Correia et al., 2018). These systems also provide a wide range of ecosystem services and public goods (Bugalho et al., 2009; Gómez-

Sal, 2000; Castro et al. 2009), which are of critical importance to well-being (Surová et al., 2018) besides representing landscapes with strong identitarian features.

However, these systems are threatened by several factors as overgrazing (Sales-Baptista et al. 2015; Plieninger 2007; Pulido and Díaz 2005; Godinho et al. 2016), fires (Guiomar et al., 2015), drought (Camilo-Alves et al., 2017; Acácio et al., 2017), plant pathogens (Camilo-Alves et al., 2013), insect pests (Tiberi et al., 2016, Branco et al., 2014) and habitat fragmentation (Nieto Quintano at al., 2016), aggravated by climate change that has higher impact on the Mediterranean region, enhancing all these threats to oak systems (IPCC 2014).

Holm oak acorns are generally more edible than acorns coming from the other oak species, but this varies widely with the holm oak trees that have a large genetic diversity and local variability (Mason 1995) in the characteristics of the acorn they produce. This is a species mechanism to prevent pests like *Curculio elephas* Gyll. (Coleoptera; Curculionidae) and *Cydia* spp (Lepidoptera, Tortricidae) (Gea-Izquierdo et al. 2006, Branco et al. 2014).

Thus, acorns may have a higher or lower tannin content, which gives it a bitter taste, but also antioxidant characteristics and lower digestibility, and may have a higher or lower sugar content. In order to increase the sugar content, it is advantageous to wait for the full maturation of the fruit, which occurs between November and December (Ferraz de Oliveira et al., 2012). To reduce the tannin content there are several techniques like leaching in cold water for several days, cooking or dehydrating them, or the easiest one that is to choose trees that already have acorns with less tannins since they keep this characteristic from one year to the next (Fonseca & Themudo-Barata, 2018).

Human consumption of acorns is a very old practice recorded through archaeological findings all over the world oak distribution area (Bainbridge, 1985). In Portugal, we have records of this consumption since the Bronze Age (Mattoso, 1993) and throughout the different periods of history (Alarcão-e-Silva, 2001; Amorim, 1987; Branco et al. 2003; Fonseca, 2004) until more recent times (Ferrão & Ferrão, 1988; Fonseca & Themudo-Barata, 2018).

Having reached the twentieth century, with the gradual improvement of populations living conditions, only moments of crisis, linked to periods of food shortage, allowed the maintenance of this habit of acorn consumption.

The period that coincided with the Spanish Civil War (1936-39) and the Second World War (1939-45) was one of crisis and famine, subjecting much of the country, namely the Alentejo, to conditions of extreme difficulty that hit with especial severity the classes of rural workers. Situations of low-income families with large offspring and nothing to eat are yet nowadays described, so each one did what he could, and this often involved robbing richer families' productions and consuming wild products, even when this meant its collection on other people's land (Fonseca & Themudo-Barata, 2018).

It is still possible to know the uses that have been made of acorns during this most difficult period. Acorns were collected in the surrounding territory of its collectors. As they are not the result of deliberate and intensive agricultural production, they have a higher nutritional value compared to nutrient intensive and extractive agricultural production. This is one of the reasons why this product maintained its nutritional value similarly to other products that were collected in the wild during this crisis period. Acorns are rich in carbohydrates, antioxidants, oleic and linoleic acids, clearly contributing to the maintenance of the health of all who consume them (Silva et al, 2016; Ferraz de Oliveira, 2012; Akcan et al. 2017).

During this period, collection, preservation and confection techniques were developed to make better use of this food and improve its characteristics and digestibility (Fonseca & Themudo-Barata, 2018).

After the Portuguese Revolution of 1974, improved living conditions led to an almost complete abandonment of this product for human consumption, which was reduced to very sporadic consumption and almost only two recipes – boiling them in water or roasting them near the fireplace embers.

Meanwhile, different environmental and social challenges, resulting from a resource exploitation model that has pushed human and natural systems to the limit, raised the need to rethink our strategies for resource exploitation and management, including resources needed for food production (FAO, 2017; De Schutter, 2010; IAASTD, 2009). Among these challenges, especially related to food and food production, we highlight climatic change, which has higher impact in the Mediterranean, causing more diseases and lower water availability, as well as lower availability of fossil fuels and other non-renewable raw materials or the growing social inequalities, reflected in the access to adequate food (IPES-Food, 2017; HLPE, 2017).

In this context, Portuguese government alongside other countries, created a set of planning tools as the Carbon Neutrality Roadmap 2050 (RNC), the National Energy and Climate Plan 2030 (PNEC) and a National Strategy for Adaptation to Climate Change (ENAAC). The ENAAC points out Agriculture, Forestry and Fisheries as one of the 9 key sectors where more can be done to avoid more emissions and to retain more carbon in the soil. According APA (2017) inventory about greenhouse gases in Portugal agriculture is responsible by about 10% of these emissions. The PNEC points out, as action plan, investing on renewable energy and on higher efficiency on its use, but this strategy has limitations and cannot be considered alone to overcome the current climate challenge.

At the same time an estimated amount of 1,3 thousand million tonnes of food suitable for human consumption is lost or wasted worldwide, annually (FAO, 2011). The estimation of the food wastage footprint carried out by FAO (2014) concluded that the costs of this food wastage correspond, annually, to 2,24 billion euros, plus 340 thousand million euros of costs to compensate damages due to the emission 3,5 gigatons of Carbon Dioxide and other gases contributing to climate change, beside costs linked to water reduction and reduced population health due to the exposure to pesticides. (FAO, 2014). In this context it is of major importance a more efficient use of the food produced, its fair distribution among population, besides a change in consumption habits through more sustainable patterns and the introduction of other alternative food sources including non-conventional edible plants (Pires, 2018).

Consumers also reflect these concerns about environmental and social challenges (Schmidt et al. 2016) leading to a resurgence of the interest in the rural, authentic and ecological consumption (Surová et al., 2014; Warrington, 2008, Tobler et al. 2011). In this sense, the consumption of products made with acorns represent thus, for their consumers, both a rescue of traditions and a support to systems recognized as sustainably managed. For producers it represents a new source of income from systems with which they often maintain a relationship that alternates between the drive of sustainable exploitation and the need to survive in a global market economy (Pinto-Correia & Azeda, 2017).

In this way, this renewed acorn consumption can represent both the emergence of sustainable production chains in response to consumers expectations about more ecological and socially responsible products, or an appropriation of these expectations by intensive and unsustainable production methods where the pursuit for profit outweighs the maintenance of more sustainable production systems.

In this article we will develop the concept of retro-innovation, describing some of its features and we will make use of acorn consumption in Portugal, in the past and in the present, to illustrate how we can use this concept in order to conceive environmental and social sustainable productive systems that respond to present and future challenges.

Theoretical framework

Retro-innovation is a concept that appeared associated with Marketing (Brown, 1999; Castellano et al., 2013; Loucanova, 2013, 2015; Amsden et al.; 2012; Chunduri, 2013; Frei, 2008; Leberecht, 2013) describing the creation of products that meet the need of consumers to use objects or live experiences from the past. The consumption of retro-innovation products is described as a consumers' search for reconnection to "something essential that appears to be missing from our modern lives" (Zack Sultan Blog, 2013), through heritage, tradition, nostalgia or revival (Castellano et al. 2016). Chunduri (2013) divides retro-innovations into three categories: the ones that authentically mimic a product or experience of the past to transport the user back into a gone era; that use a nostalgic format to meet a new need; or that use a new format to meet an old need. The underlying goal of these authors is to find new ways to promote economic growth or to understand why not always more technology leads to more sales. Bravo (2019) uses the concept of retro-innovation as a way of food companies seek for quality and healthiness in the innovation for sustainability framework. Stuiver (2006) highlight the potential of retro-innovation or "the retro side of innovation" to develop viable alternatives for rural development using a Strategic Niche Management approach. This author describes retro-innovation as "developing knowledge and expertise that combines elements and practices from the past (from below modernization) and the present and configures these elements for new and future purposes". She highlighting its role as an alternative to current development regimes focused on achieving more productivity, efficiency, and export-oriented agriculture in an increasingly globalized and liberalized world, which requires farms of increasing size, specialization and intensification levels. Stuiver also draws attention to the role of research as facilitator of retro-innovation by producers.

In this paper we propose that retro-innovation can be considered as a way of adapting consumption habits towards better resources' allocation, expected to be scarce in the future, such as fossil fuels, water or non-renewable raw materials as well as to a more equal distribution among its potential users. Retro-innovation can thus contribute to a low carbon economy, in order to deal with Climatic Change and the growing social inequalities.

This proposal is based on the fact that products and techniques developed in certain periods of our history result from resource-constrained environments, as the ones created before the wide use of fossil-fuels, the easy access to non-renewable inputs, the vulgarization of irrigation systems and the widespread dissemination of a market economy. These resource-constrained innovations can refer not only to tools or technical devices, but also to production processes, resources used (Fonseca & Themudo 2018) or even to governance practices linked to the use of these resources (Antunes 2015; Dias 1983, 1984). They were, as described by Pisoni (Pisoni et al. 2018) frugal innovations, that can be adapted nowadays to more sustainable practices and consumption.

The European Union has proposed in its Policy Brief (2014) on research and innovation to address major global challenges, that frugal innovation should also be considered in more advanced economies, in addition to the traditional focus on less developed economies.

Retro-innovation has, in this sense, the following characteristics:

- Use, as basis for innovation, the ancient knowledge about products use, processes as well about their distribution among their potential users, developed before the widespread availability of fossils fuels and the ensuing dominant modernization project;

- Usually it is still possible to find a body of knowledge about tools, processes and management practices, linked to resources use;
- It is territorialised in the sense that linked to the territories were the previous technologies were developed, namely cultural and biophysical characteristics;
- It can be implemented in developing but also developed economies, once ancient knowledge does not obey to the current distributions of wealth according to which we distinguish developed from underdeveloped countries;
- Because it is based on traditional practices and local resources it has a high potential for acceptance by both local users and visitors, contributing to the reinforcement of the identity of each region;
- It was developed by local population, without scientific and inaccessible knowledge for its design, resulting in appropriate technology instead of high tech, thus being capable of re-appropriation by a wider range of users;
- Once the ancient knowledge was often consolidated in periods of scarcity of resources, it has the potential to offer products and processes that make low use of non-renewable energy and raw material and to developing deficit watering systems.

2. Methods:

To illustrate the potential contribution of retro-innovation to deal with the global challenges we face, we focus on acorn use in Portugal throughout history.

Our approach to acorn consumption was dived in two main periods (Table 1): A - in the twentieth century and B - in the twenty-first century until nowadays. Data collection followed different procedures according to the period studied. For period A a literature review was conducted as well as semi-structured interview (Annex A) to 20 respondents of an intentional sample, usually but not always, users of retirement homes, of Montemor-o-Novo and Évora municipalities from Alentejo region, besides a key informant, part of one of these retirement homes. These interviews were recorded, transcribed and numbered. Respondents were asked to name of the wild products they consumed, excluding medicinal and aromatic plants and cultivated products. This information was supplemented with some bibliography that addresses the same period and the same region. For period B, on the actual use of acorn as food for humans, a questionnaire (Annex B) was made to the main companies identified as processing acorns today. From the eight companies identified only seven managed to get the data requested. These companies where identified with a number to maintain anonymity. For the later, the questionnaire was replaced by an interview that allowed a more detailed description of the current situation regarding the acorn row in Portugal.

Table 1 – Approaches according each period studied.

	Period A	Period B
Corresponding period	in the twentieth century	in the twenty-first century until nowadays
Methods	• literature review, • 21 semi-structured interviews (Annex A)	• Questionnaires to eight companies processing acorns (Annex B)
References	Fonseca & Themudo 2018	

Data collected for period A comprised other products besides acorns and were divided by collection, storage and confection methods, besides the confection of animal feed. Living conditions and political conjuncture were also described in order to understand the reasons underlying the consumption of wild food products in this period. The questionnaires used to evaluate the recent evolution of new companies based on acorn processing (Period B) were sent by e-mail, after a contact by phone or personally. One of these companies did not answered by lack of data, but a later contact by phone allowed to add enriching aspects to data obtained from the questionnaires.

3. Results:

3.1 Acorn use in the twentieth century

From the interviews we realize that people in Alentejo used to distinguish several varieties of holm oak acorns: the long and short *bical*, the normal acorn and the *castanhola*[50]. However, although *castanholas* are the most appreciated, they are also relatively rare and, according to Salgueiro, are sparsely distributed among the other varieties of holm oaks.

Acorns quality remains constant from one year to the other, so shepherds and country people were aware of the oaks that gave good acorns. Another strategy was to taste the acorns of a tree: if some were of good quality, all others would be too, according Salgueiro (2005): “We always tasted the acorns before we caught them.” Or as one woman describes in Fonseca (2007): “I ran ahead of the pigs that were grazing around the school to steal their sweet acorns from the ground, which served as bread coverage.”

Salgueiro (2005) describes: “My mother used to send me with my sister to fetch them and each one brought a basket full of them. By the end of the day, there was a huge amount at home, enough for several days. We got them because the guards didn't care about the kids. If my mother or father would catch them, the guard would report to the authorities immediately.”

But not all *Montado* owners had this position with regard to the poor who came to catch acorns on their farms. Some lived better with this recollection, as it was the case of Herdade do Freixo do Meio owner, Alfredo Maria da Praça Cunhal as described by Salgueiro (2017): “(…) In that estate of Freixo there was a lot of acorn. (...) My uncle and my father were going to fill the bags at night. See, from Gafanhão[51] to Freixo, by foot until Foros Vale de Figueira[52], the distance that it was. By foot, those two souls were carrying bags full of acorns. (...) Those souls came with those bags full of acorns, they came here, they went to sell to the Maia[53] area, to the farmers, to men who had pigs in sties, to gain weight.”

These were the “*boleteiros*[54]” described by Silva Picão (1903) as those men who, at the season of acorns, invaded the others’ *Montados* collecting large amounts of acorn and then selling it as their own. Silva Picão also describes that these “*boleteiros*” would be unemployed rural workers or *Malteses*[55]. This acorn would be used for its own food or for sale. This was an institutionalized

[50] *Castanhola* comes from *castanha*, the Portuguese name to chestnut, because these acorns are the most similar to chestnuts, both in shape and taste.
[51] At 1 Km from Montemor-o-Novo
[52] At 12 Km from Montemor-o-Novo
[53] 3 km from Montemor-o-Novo
[54] *Boleteiros* from the Portuguese word for acorn – *bolota*. So, men that pick-up acorns.
[55] People without fixed residence or employment who moved around the territory and lived on what they stole or from small temporary activities.

robbery, to which some owners closed their eyes, because they knew the situation of need to which Alentejo workers were subjected (Cutileiro, 1977).

But as Madureira (2002) points out, this acorn gathering activity was also part of the temporary farming activities carried out mainly by women and young people who were hired to catch acorns that fell from the trees and were then bagged to be given to pigs during periods when they did not exist in the *Montados*. Frequently these collected acorns were stored in anoxic water tanks in order to lose tannins and to last longer. Examples of this are the large tanks belonging to the Praça family in Montemor-o-Novo, which, although they no longer perform this function, still retain their original structure.

Often the activities of keeping pigs and collecting acorns were connected, the first being carried out by children at the beginning of their working life in agriculture, as Madureira (2002) points out. Later these same pig keepers were "hired, as was the case in Palma, to pick-up acorns that fell from the holm oaks to be bagged and kept to feed the pigs in the winter."

Some of the interviewees (E1, E4) describe how women walked in groups picking acorns among cereal crops that stretched beneath the holm oaks canopy. The acorns were later bagged and used to feed the enclosed animals.

Often, they were consumed raw, but they were also, often cooked and baked among the ashes of the hearth, as they were preferred. In both cases it was necessary to shred them so they wouldn't explode in the fireplace or cook better in the pan. Salgueiro describes how they go well with lemon bark, melissa, cinnamon or even with fennel and salt (E1).

There were techniques for storing acorns to serve as food for the rest of the year (E4). With this purpose they were *aveladas*[56], that is, dried with the shell in dry places and turned frequently, in order to avoid the humidity and the resulting mold. After a few weeks they withered, lost moisture, but became sweeter and softer, losing some of the tannins they still had. They were then stored in wooden chests and lasted the rest of the year, becoming tasty and keeping some moisture. Guarantees who proved, (E4) that they were very good. Another technique, (E4) which further ensured better preservation and flavour was to bake the acorns lightly, peel and smoke them in the fireplace chimney, in baskets made of olive branches, for at least two weeks (E9).

In the municipality of Montemor-o-Novo some of the interviewees talk of cooking acorns with sprouts (E2), acorns with honey (E4), acorn marmalade (E4), rice cooked with dehydrated acorns, served by Easter (E4, E19), chickpea pastry made with acorns (E19), and other specialties whose recipes, for lack of continuity, have been lost. As noted by Salgueiro (2005) "Still the roasted and milled acorns make a good coffee, healthier than the other."

Another use given to acorn was its transformation into oil and animal feed. The Évora processing unit worked between 1967 and 1979 and transformed about 250 Ton of acorns per day during the acorn campaign, according to its manager. Acorns were transformed into pure acorn or mixed oil for human consumption, and acorn flour that was sold to another factory to mix with other products to prepare animal feed. The rise in labor prices led to its end and the closure of the structures used in this transformation.

[56] From the portuguese word *avelã* - hazelnut, because they ended up with a taste similar to that of this fruit.

3.2 The period of abandonment of acorn consumption

However, in the post-revolution period, the living conditions of rural populations improved. Acorn consumption has been virtually abandoned, limited to a very sporadic consumption of roasted acorns.

The amount paid for labour has increased substantially, making some of the practices described above unfeasible, such as hand picking of acorns from sown fields, to preserve them in anoxia in farm ponds and feed animals later or hand picking of acorns from the fields, usually to sell to farm owners, or to sell to the acorn oil factory.

3.3 The resurgence of acorn use

The support of Portuguese Innovation Agency to the introduction of a master in an organic farm in Montemor-o-Novo, through a grant whose goal was developing acorn-based products, lead to the first of these products in the market in 2008. From the seven companies interviewed, two started acorn processing on 2014, two in 2016, and the latter two in 2017. Other small experiences, in a pre-entrepreneurial phase, are distributed a little throughout the country, but whose activity is developed irregularly and with very low incomes.

As a result of this increase in the number of companies, the development of new products and their consolidation in the market, the overall use of acorns has increased from 50 kg in 2008 to 6730 kg, ten years later. However, the pioneer in this transformation continues processing 74% of the acorn, transformed by these companies, followed, with a great distance, by one of the newest companies that processes 10% of all the acorns and another older one that processes 9%. The rising on acorn processing was not uniform. A significant increase in the amount of acorn processed from 100% or below this value, of annual growth in the first years to a sudden increase of 319% in 2015, corresponding essentially to the growth in this transformation by the pioneer company 4, which alone is responsible for 500% of acceleration of this activity in the same year. In the following years, the acorn processing activity continued to increase, but more slowly.

Only companies 1, 3 and 7 sell their products to other European countries. While for company 1 this is a growing strategy that started with 20%, to 30% and 35% in 2016, 2017 and 2018 respectively, and for company 2 corresponds to 30% in the two last years, the later, company 7 exported 90% of its production in 2018. Even company 8 had a large order for the Netherlands, which at the time was unable to answer because the lack of acorn flour.

Income providing from this processing also increased in the same order from 50 € to 16 770 € with company 4 earning 38% of the total income with this activity in the group of companies, followed by company 1, with 38% and company 2 that earned 32% of the income with acorn-based products. This company 2 corresponds to a special case because it is quite new, starting its activity only on 2017 but processing, already in this year the same quantity than company 4, the pioneer company, corresponding to 4000 Kg. On 2018 company 2 processed 8000 Kg of acorns against the 4458 Kg processed by company 4.

With regard to the yield obtained with the acorn products, values range from 0.93 €/kg in company 4 to values of around 40 €/kg in company 5 or 13 €/kg in company 7. These values correspond to different selling strategies ranging from company 4 that invests clearly in the production and sale of acorns with low processing levels (shelled acorn or acorn flour) to provide other companies and individuals for further processing, to companies that sell high value-added products like acorn bonbons or acorn buttercream.

The products created by the eight companies are presented below in Table 1.

1	Fresh whole acorns
2	Frozen whole acorns
3	Peeled and dried holm oak acorns
4	Peeled holm oak acorn flour
5	Toasted flour for infusion
6	Toasted flour for coffee
7	Toasted flour for infusion, in single sachets
8	Acorn milk
9	Acorn buttercream
10	Acorn and carob buttercream
11	Acorn and lavender buttercream
12	Acorn and thyme buttercream
13	Organic acorn jam
14	Organic acorn and peppermint jam
15	Chocolate candies stuffed with acorn flour
16	Cookies with seven different flavours including one vegan, one without wheat and one special for diabetics
17	Bread with sweet and salty stuffing
18	Bread
19	Cornbread
20	Toasts
21	Biscuits
22	Salty pate
23	Soup
24	Hamburgers
25	Acorn meatballs
26	Acorn delights
27	Acorn cream pastry
28	Chocolate tablet with acorn
29	Acorn cupcake
30	Acorn sugar
31	Yogurt

Some of these products are regularly sold while others constitute more punctual experiences. One of such cases is acorn sugar, for which an enzyme must be used and is therefore, according the company owner, a more sophisticated process and in need of efficiency improvements in the production process.

3.4 The demand for innovation

A global trend of these products has been the improvement of their characteristics. According to the owner of company 8, acorn flour he uses has more constant and reliable characteristics, allowing the establishment by this processor of a fixed recipe, without the need for constant adaptations. As he explained, this has to do with the dehydration process of acorns in the supplier company, company 4, that is now slower but more uniform, allowing to obtain a fine and uniform flour.

As explained before, company 4 was the first one starting acorn processing. The owner explained that in 2015 they decided to take acorn industry more seriously. Several methods have been tested then, namely those already developed for olive harvesting, such as vibrators or sticks with motor. They also tested acorn aspiration from the ground using vacuum cleaners and sweepers. Later on, they decide to pay to pickers and actually, the model is to pay, a little bit more, to two pickers by already chosen acorns, without visible insect holes and separated between holm oak and cork oak acorns.

Shelling and conservation of flour and acorns also presented problems in need of solution. The first solution was to freeze the acorns right after picking and send them to a chestnut processing factory in the north of the country. Here acorns where subjected to a thermal shock, in addition to eliminating the fruits affected by insects or already rotten using an optical eye. This process included the peeling of acorns and totally eliminated the tannins. This latter characteristic proved to be negative as the tannins allow conserve the flour, this without tannins degraded very rapidly, leading to high losses. This solution has proven, also, to be extremely costly being replaced by the current solution. After realizing that it would be easy to peel the acorns if they were dried, the next step was to recreate the old smoking process over a board made of canes. Thus, a temperature-controlled oven was built which, instead of roasting the acorns, dried them. The bark is thus more easily removed and the tannins, preserved, resulting in products with a longer shelf life, more uniform characteristics and a large reduction in production costs.

Although a path has already been made, in company 4, in the innovation process around acorn processing, other needs are still pointed out by the owner. Namely tree harvesting equipment adapted to a more fragile tree in relation to olive trees, equipment to collect acorns from the ground. However, the owner acknowledges that the current model of buying acorns from pickers is less aggressive to the trees, more socially responsible and allows to keep noisy machinery out of a system characterized by silence and tranquillity.

Acorn sugar is produced though a process similar to the one used with corn starch in the production of corn jelly and sugar, but industrialization is pointed as a solution for its viability as it requires its own large equipment that is difficult for small companies to own.

A set of chain companies, is the solution also pointed out by this owner, to get the most out of acorn. Thus, in a circular economy logic, an acorn oil extraction plant would be followed by an acorn sugar extraction company and finally one for the incorporation of acorn flour into animal feed, replicating what has already been done in the 1970s in this region.

An acorn yogurt and industrial cookies were also been tested, but its viability has been compromised, in both cases, by lack of product.

In order to reinforce innovation in this sector, company 4 has been in regular contact with several academic and industry institutions.

The owner of this company concludes by explaining that despite processing around 5 ton per year, he could process until 200 ton, and that a producer organization around this product would allow to produce a lot of food for many people.

Some products require higher technology then other. Between this one can include acorn milk, that tends to be a very suitable medium for the proliferation of microorganisms, so it requires a pasteurization process that does not degrade the remaining qualities of the product. This implies hi-technology devices.

3.5 Hi and low tech

According Khalil (2018), technology is a word that comprises the materials, systems and construction methods, and that may be implemented at a higher or lower level. In this sense, low-tech is defined, by opposition to high tech, as making use of simpler technologies, being more easily used and adapted by individuals or small groups with basic knowledge. Instead, high-tech makes use of all the available modern potentials, through the implementation of advanced procedures, requiring experts to its construction, use, maintenance and adaptation (Khali et al., 2018). Table 2 summarizes the key features of these two types of technology.

Table 2 - Key features of Low and High technologies.

		Low-tech	High-tech
1	Complexity of technology	Simple	More complex
2	Knowledge used	Lower and traditional knowledge	Intensive experts' knowledge
3	Link to tradition	Strong but not always	Barely
4	Investment of capital	Low	High
5	Users	Individuals or small groups	Large groups
6	Strategies	Passive systems	Active systems
7	Methods	Simple	Complex
8	Energy requirements	Low	High
9	Crossed-compatibility	Yes	Yes
10	Resources use:		
	Provenance	Local	Global
	Quantity required	Low	High
	Availability	Easily available	Restricted, with need of extraction and purification
	Quality	Any	High
	Transport distance	Short	Long
11	Final product quality	Adequate	High
12	Available to modification or adaptation by users	Easily	Barely
13	Maintenance	Easy at low price	Difficult and costly

During period A it is possible to identify a set of older or newer technologies. While its majority are of the low-tech type, some can be considered as being high-tech.

Low-tech:

- Knowledge of trees that give the sweetest acorns
- Acorn picking by hand
- Selection by hand of acorns without holes and between holm oak and cork oak acorns
- Conservation to human consumption making use of the tannins naturally present in acorns by slow drying in aerated places and turning acorns frequently, in order to avoid the humidity and the resulting mold

- Conservation, to feed the animals out of acorns season, in anoxic water tanks with salt in order to lose tannins and last longer
- Several recipes requiring an oven or fireplace, honey and other ingredients locally available
- Acorns broken with a heavy rock to feed poultry

High-tech:

- Acorn oil extraction plant
- Animal feed, out of acorns season, with rations including acorn waste resulting from acorn oil factory

During period B, we identify several technologies, to treat acorns that can be integrated into hi and low-tech.

Low-tech:

- Acorn picking by hand
- Selection by hand of acorns without holes and between holm oak and cork oak acorns
- Conservation using tannins naturally present in acorns
- Acorns drought using a traditional smoking process in a temperature-controlled firewood oven
- Shelling by compression of dried acorns

High-tech:

- Tree vibrators for acorns harvesting
- Sticks with motor for acorns harvesting
- Vacuum cleaners for acorn aspiration
- Sweepers to gather the acorns and facilitate the collection
- Shelling and conservation by thermal shock in a chestnut processing factory
- Selection of healthy acorns using an optical eye
- Enzymatic process to produce acorn sugar
- Industrial cookies
- Yogurt manufacturing
- Pasteurized acorn milk (Sardão et al. 2019)

Meanwhile we take notice of other practices such as acorn production in super intensive holm oak plantations to feed black pigs in captivity.

4. Discussion

Through the data previously exposed we can realize that acorn consumption has been a constant throughout the history of Portugal.

It was identified also a recent interest in the use of this product and the recovery of some recipes, materialized in a set of acorn processing companies that have appeared in Portugal. The reasons behind this renewed interest are several, according the different actors in the value chain. Producers seek mainly income diversification, while consumers have, as main drivers, the link with tradition, health and the opportunity to consume products providing from systems acknowledged as sustainable.

In addition to these drivers, both globally and in Portugal, we face new challenges such as climate change and resource depletion that require adaptation and minimization measures (APA, 2015; APA 2019). The need for developing decarbonisation measures is difficult to match with the need to produce food for a growing population. However, it is recognized that a large part of the problem lies more in an adequate distribution of available production and in increasing the quality of food produced than in simply increasing the quantity produced.

The development of sustainable food production systems can be one way of combining food production with environmental preservation. Wild foods as acorns are an excellent opportunity in this context once they require less water, plant protection drugs, or fossil fuels to agricultural works. In their quest for innovation to address different problems related to the acorn transformation process, small and medium-sized businesses tend to make use of low-tech or appropriate technology practices, often adapted from older practices in a retro-innovation process. Processes involving more sophisticated technologies such as pasteurization, the manufacture of acorn oil or sugar through an enzymatic process are only accessible to larger companies that process large amounts of acorns, thus requiring an intensification degree that is hardly compatible with the sustainable exploitation of an extensive system such as the Montado or the oak forests of northern Portugal.

Accompanying the growth in the acorn processing sector, non-sustainable productive systems appears, as acorn production in super-intensive holm oak irrigated plantations.

As Winner (1985) refers, the beginning of technology establishment is when there is more freedom of choice about what kind of technology will be adopt in a sector. As certain choices are made in one direction or another, between more complex or simpler technologies, between the possibility of they being appropriated by all or only by a restricted group of great transformers, initial freedom is restricted and only with much difficulty the paths chosen can be reversed.

In what refers to the acorn sector, this is the perfect time to think about the kind of production we want to promote: one that meets consumer expectations of sustainable consumption or a business-as-usual model, with the consequences we all know.

Attention should be paid to ensure that, in the path of retro-innovation, the sustainability of ancient practices and the arguments that may underpin consumer preferences are not lost. In order to maintain their sustainability, certain aspects of the innovation of these products must be monitored, such as the expenditure of energy and raw materials in the manufacture of new products, the maintenance of a sufficient level of technology to enable innovations to be appropriated and disseminated by others, the distance between the place of production and processing, the processing methods, the destination of the waste from this processing.

This sustainable retro-innovation may be of interest not only in the case of acorn, but also for so many products under the name of wild edible foods, or underused crops, whose recovery has increasingly been a goal of different scientific entities. In these cases, too, it is important to consider what kind of food sectors we want to develop, what goals we want to serve: a sophisticated industrialization process, highly resource demanding and that can only be understood and managed by a small profit-earning elite, or a lower-tech and low-resource demanding process that allows broader income distribution for larger fringe of the population while responding to the major environmental challenges we face?

As Pansera argues (2013, 2018) frugal innovation *per se* is not enough to solve environmental and social problems. This must be embedded in social and institutional eco-innovation. Also, in this aspect, retro-innovation can provide a contribution for developing new social arrangements based on ancient practices around work distribution, collective activities or adequate technology that allows a more democratic appropriation of innovation.

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DECOLONIZING NATURE? DOMINANT WORLDVIEWS AND WORLDVIEWS OF AGROECOLOGICAL FARMERS IN GERMANY TO ADDRESS THE GLOBAL ENVIRONMENTAL CRISIS

Stephanie Domptail, Jennifer Hirsch, Ernst-August Nuppenau

Institute for agricultural policy and market research, University of Giessen, Germany.

Abstract

In Western Europe, farmers are embedded in a secular culture. This culture, characterized by a worldview where man and nature are separated and opposed, individualism is highly valued, capitalism rules exchanges and where the end production of food, rather than the process of food production, is central to food systems.

Agroecological approaches aim for farmers to entertain fundamentally different relationships between agriculture and the natural/social environment. Such a reconnection with the environment requires that farmers act based on an alternative worldview. Agroecological movements claim that their practices are based on a holistic worldview of nature. Yet, we currently have little cultural information about agroecological farmers in Western Europe.

The contribution thus explores the worldview of agroecological farmers in Germany in order to identify how they conceptualize their connection with nature and whether new connections to people are implied as well. More specifically, we attempt to answer the two questions: (1) How does the worldview of agroecological farmers in Germany make use of a decolonized perspective in order to reconstruct their relations to nature? And (2) Which place do farmers perceive for themselves in their environment with regard to important societal challenges such as climate change?

The paper first analyses the fundament of the Western worldview and ontological principles of alternative worldviews. The Human-Nature connections are interpreted making use of the Gaia theory and the integrative worldview. It then presents a reconstructive analysis of narratives collected from agroecological farmers of one farmer union via in-depth interviews. Results show that both colonized and decolonized perspectives of nature co-exist and that farmers perceive their activity as a responsibility towards the environment and society at the local, landscape and even global scale.

Investigating the ontological basis for the practice of agroecology in the Western European context can reveal fundaments to foster the agroecological transition and insights to the role agroecological farmers want to play in the wider food system.

Introduction

According to the Millennium Ecosystem Assessment, agriculture contributes more to the destabilization of ecosystem functions than any other single human activity (MA, 2005). Agriculture, forestry and other land-use activities accounted for 23% of the total net anthropogenic emissions of greenhouse gas (IPCC Report, 2019). The use of the Earth through hunting, foraging, land clearing and agriculture has always had some transformative effects on nature (Ellis et al., 2013). However, modern industrial agriculture has intensified and enlarged these effects spawning a global environmental crisis (Callicott, 1990). Litfin (2003) and Levins (2006) refer to a megacrisis "expressed in increasing demand on depleting resources, pollution, new and resurgent diseases, climate change, growing inequality, increased vulnerability to disasters of all kinds, loss of biodiversity, the erosion of productive systems, and recurrent conflict within our species." (Levins 2006:35).

At the same time, no other human activity is as basic and central as food production for human sustenance. Thus, agriculture implies both Man's use of nature and our dependency on it (Sanford, 2011). Agriculture represents the cornerstone of Human-Nature interaction where both humans' and Earth's needs may be reunited. Thereby, it has the potential to contribute greatly to solving the global environmental crises. The magnitude of the challenge may arise from its root in our culture's philosophy, as suggested by environmental sociologists.

Capra (1984) also understands the numerous environmental problems as the expression of a single crisis of perception. It "derives from the fact that we are trying to apply concepts of an outdated worldview – the mechanistic worldview of Cartesian-Newtonian science – to a reality that can no longer be understood in terms of these concepts." (Capra, 1984: 15-16). Levins (2006) points to a crisis of relationship, rooted in "a pervasive and intensifying dysfunctional relationship between our species and the rest of nature".

Agriculture, as all human activities, is the expression of human culture. According to Callicott (1988:3) a culture's agriculture reveals its "fundamental metaphysical beliefs and values. The beliefs characterizing Western Culture are "the emblematic faith in technology, the doctrine of progress, the centrality of instrumental reason, the sanctity of individual freedom, the denial of the sacred", according to Litfin (2003: 30). She identifies these beliefs as "sources of an environmentally destructive cultural tendency". These beliefs and alleged causes of our complex crisis are rooted in the same 'philosophy', which is known as the Western/secular/mechanistic worldview or the Cartesian paradigm. Kirschenmann (2005) argues that worldviews – and today the Western worldview - shape both our perceptions and actions. Thus, worldviews are fundamental in the transformation towards a sustainable agricultural and food system.

In the science arena, environmental sociology attempts to define the fundaments of an "integrative" or ecological worldview that could reunite Earth and human needs and lead to a more sustainable Human-Nature relationship. The proposed worldview is rooted in systems' theory and stresses the co-evolutionary relationship between mind and action, between worldviews and the way society constructs its relationship to nature and its own structures. In parallel, agroecology proposes as a set of alternative farming principles (Nichols et al., 2017), and is presented as a paradigm for an alternative food system (Gliessman, 2016; Oehen et al., 2015) in an attempt to resolve environmental and social problems. Its transformative potential (Giraldo and Rosset, 2016; De Schutter, 2011) rests, according to De Schutter (2017), on the fact that agroecology is based on an alternative, radically different Human-Nature relationship, that is, a new worldview. This paper seeks to bring together these theoretical and practical attempts to construct a worldview that sustains a new and sustainable relationship between Man and Nature.

What would be key concepts in a new worldview transcending the Human-Nature divide and inspiring a more sustainable agriculture? In comparison, how does the worldview of agroecological farmers in Germany make use of a decolonized perspective in order to reconstruct their relations to nature? Which place do farmers perceive for themselves in their environment with regard to important societal challenges such as climate change?

The paper first retraces the roots of the worldview that industrial agriculture is based on, and introduces an alternative integral worldview. Since stories people tell and rely on to see the world and stories' metaphoric and narrative realms are the expression of worldviews (Litfin, 2003), this paper presents in a second step a reconstructive qualitative analysis of the worldview of agroecological farmers in Germany and of their perceived role in the global environmental crisis.

Investigating the ontological basis for the practice of agroecology in the Western European context can reveal fundaments to foster the agroecological transition and also insights into the role agroecological farmers want to play in the wider food/environmental system. Indeed, a new metaphor can further help to set in motion a cognitive transformation at the level of a whole society by raising awareness of the faulty system and by calling the old model(s) into question (Hirsch & Norton, 2012).

Background: the emergence and establishment of the Western worldview in agriculture

The emergence of a mechanistic worldview of nature

Capra (1984) describes the dominant worldview in Europe in pre-modern times prior to 1500 as organic. Science generally pursued the development of a profound understanding of nature in order to live in harmony with it. In contrast, contemporary science seeks to predict and control. At the root of contemporary science is the scientific revolution, which relies on three major premises.

First, the scientific revolution separated objects from subjects. Natural sciences became exclusively occupied with material objects (matter) and their quantifiable and measurable properties. They excluded other properties, such as color, sound, smell and taste, and in general life and spirituality (mind) (Capra, 1984). The belief that certainty in knowledge can be achieved only via the separation of mind and matter became central to the Western worldview and science.

Second, a great contribution to science was the analytical scientific method developed by Descartes (in the 17th century). Nature was portrayed as a machine, as "working according to mechanical laws, and everything in the material world could be explained in terms of the arrangement and movement of its parts." (Capra, 1984:60). Animals were production automata. However, this analytical method has resulted in a fragmented vision of the world, coined as reductionist. The term reductionist refers to "the belief that all aspects of complex phenomena can be understood by reducing them to their constituent parts" and ignoring the role of relationships between parts" (Ibid.).

Finally, another important turning point in the representations of humans and nature was the incorporation in the Western worldview of Bacon's idea that "knowledge is power" and that man, through science, could control nature. This contributed to the further transformation of the ancient concept of a nurturing Mother Earth into the patriarchal metaphor of the world as a machine (Capra, 1984).

A primary consequence of the Cartesian division between spirit and matter was that achieving an objective description of nature became the ideal of all science (Muraca, 2016). Second, the goal of science became the generation of knowledge that would enable the human species to dominate and control nature and to invent technologies that could modify the world (Capra, 1984:55-56; Kirschenmann, 2005).

This mechanical view on nature turned into the dominant scientific paradigm for the next three centuries and shaped our modern agriculture (Callicot, 1990). Applied to sociology, it led to the idea that human minds, as powerful mechanisms, could adapt quickly to any ecological change. Catton and Dunlap (1978) termed this powerful paradigm which underlies agrarian modernization theories in the second half of the 20th century the 'Human Exemptionalism Paradigm'. The scientific paradigm was broadened to a general Western worldview, which is summarized by Capra (1984:31) in these terms:

Belief in the scientific method as the only valid approach to knowledge; the view of the universe as a mechanical system composed of elementary material building blocks; the view of life in society as a competitive struggle for existence; and the belief in unlimited material progress to be achieved through economic and technological growth.

Western Worldview and agriculture

Callicott (1988; 1990) summarizes how the mechanistic worldview conceptualizes modern agriculture as follows: The soil is perceived as a mere physical substrate, providing space and mechanical support for plants. Plants are complex assemblages of simple elements. The (potentially engineered) DNA of plant cells produces carbohydrates, fed as energy to agroanimals, and ultimately humans. As on an assembly line, processes are broken down to the smallest steps. The "[p]roducts are standardized; scale is magnified; and crops are specialized and monocultured." (Callicott, 1988:5). Importantly, agricultural goals, such as increases in yield, pest control, soil fertility, etc... were believed to be achievable "Cartesian-style, by finding a separate solution for each and summing the results" (Callicott, 1990:41).

The modernization of farming systems involved a series of transitions: from labor-intensive to capital-intensive; from heterogeneous to homogeneous; from small scale to large-scale; from subjection to nature to domination of nature; from superstition to science; and from the production of food to the production of commodities (Levins, 2006:38). A central example of the application of the Cartesian scientific approach to farming is the work of Justus von Liebig in the 19th century. After his identification of the role nitrogen, potassium and phosphorus play in feeding plants, von Liebig argued that the labor intensive nutrient cycling practices could be replaced with the application of chemical fertilizers. He inspired farmers to abandon their mixed farming practices to turn towards the specialized production of a few high-value crops (Kirschenmann, 2005).

The dominant narratives of conquering nature and manipulating parts of a machine– which emanated from the Scientific Revolution and underlie Western agricultural practices- are (still) presented as natural and inevitable within both the scientific and the 'feed the world' discourse (Litfin, 2003:29; Sanford, 2011:289). Yet today, modern agriculture is denunciated as a form of colonialism of nature. Guzmán & Woodgate (2015) also claim that ways of farming that did not follow rules of modernity were impoverished.

The problem is that the mechanistic worldview, with its machine metaphor and the fragmentation doctrine, is too narrow. The challenge ahead of us is to abandon the dichotomies through which we see the world today, such as the Man-Nature divide, the material and spiritual divide, etc... Science, as well as groups and networks from the practice in the field, are seeking new principles and paradigms for their organization (Capra, 1984).

An integrative worldview: theoretical developments and practice in agroecology

Currents of environmentalism have developed as a response to the ecological degradation ensuing from modern instrumental usage of nature. The first current refers to exclusive conservation projects such as nature parks where Nature is seen as wild, primitive, naïve and needing (richer) human protection (from other humans). The second current refers to precision agriculture, climate-smart agriculture, nutrition agriculture and the like (Oehen et al., 2015); practices which aim at using resources more efficiently to garanty their long term contribution. These hegemonic currents of environmentalism perpetuate the dichotomy between man and nature and the objectifying and instrumentalizing view on nature rooted in modern science (Muraca, 2016.). Yet, they do not represent a paradigm shift, in which thoughts, perceptions and values would shift fundamentally (Capra, 1984).

Towards an integrative worldview – theoretical perspective

The core principles of a new paradigm shall attempt to reformulate the crucial (ethical and cognitive) questions of who we are in relationship to the environment and of how can we meet both Human and Earth needs.

A third current of environmentalism, termed environmentalism of the poor by Guha and Martinez-Alier (1997) refers to the struggles of small farmers, women and indigenous people to preserve their collective livelihoods as well as their vision of a self-determined and sustainable life in their community. Their language and narratives express

a radically different [from the Western paradigm] understanding of the relation to the 'territory,' with all its inhabitants included in what can best be called a cosmo-anthropo-vision, in which interconnection among different levels of the real (biophysical, human, supernatural) leads to specific society-nature relations and nature-culture regimes. (Muraca, 2016:35)

Escobar (2008:154) considers this a decolonial view on nature that "calls for seeing the interrelatedness of ecological, economic, and cultural processes that come to produce what humans call nature" (quoted in Muraca, 2016: 35). Two theoretical concepts help qualify the beliefs and worldview the Environmentalism of the poor is based on. These are the integral perspective (Litfin, 2003) and radical relationism (Muraca, 2016).

First, the integral perspective, developed by Karen Litfin (2003) is built on "the premise that consciousness is ontologically prior to action" (p. 29). Thus, the global problem of our relation to nature is rooted in a dysfunctional mode of consciousness. A next stage of human consciousness shall bring the understanding that humanity and nature, spirit and matter, are two dimensions of a single reality (Litfin, 2003). It foresees a unique responsability (rather than privilege) to humans to develop their consciousness and find new modes of ontologically closing the gap between mind and matter (ibid.).

Second, radical relationism argues that "relations are ontologically prior to and constitutive of entities, rather than being conceived as external link(ing) between them" (Muraca, 2016: 19). Thus, experience is created through "a web of constitutive relations that include the emotional disposition of the act of grasping itself" (Muraca, 2016: 20). Object and subject interact and co-create one another. By contrast, the Western worldview depicts objects as pre-existing substrate and fails to acknowledge these relationships. One consequence of radical relationism is the necessity to consider farming systems holistically as constituted of parts which acquire meaning through their relationships with other parts. For instance, soil fertility is the corner stone of healthy farming systems rather than the optimal concentrations of N, P and K.

New mental models to link global to local

Concomitantly to alternative ontologies, Hirsch & Norton (2012) propose that global issues such as climate change can best be addressed by defining a new metaphor of the world. This metaphor plays the role of a mental model. Our inner mental models mirror the outer reality. By changing our metaphors and values, we change our actions., A new metaphor can incite an individual as well as a society to act upon the outer world and shape the environment quite effectively (Capra, 1984). In the case of climate change, it should allow us to "think globally, act locally".

An interesting mental model for the farming issue according to Litfin (2011) is thus the "Gaia theory, an interdisciplinary scientific perspective that understands Earth holistically as an integrated, self-regulating biogeochemical system". As an archetypal, Gaia theory is consistent with and can be seen as an application of the concepts of integral worldview and radical relationism, outlined above.

Three qualities of living systems, i.e. holism, autopoiesis and symbiotic networks can help steer human systems toward sustainability (Litfin, 2011: 421). Holism is expressed in Gaia theory by the representation that Gaia (the Earth) as "the largest known instance of a living system, which in turn entails countless subsets in the form of nested living systems of biota and their environments" (Litfin, 2011: 421). Thus, system thinking opposes the thinking of production as a linear process from resource to waste. Second, autopoietic refers to the capacity of maintaining the system and its function in time. Thus, the purpose of the system, that is, the functions that should pertain, is a fundamental philosophical question. Currently, growth constitutes the accepted purpose of the global economy. Yet, its infinite desirability on a finite planet causes Gaian-scale perturbations. Rather, the integrity and the stability of the Gaian system should become the core human purpose (Litfin, 2011:421). The third quality of living systems, the symbiotic networks, refers to the idea that the world consists of relations among objects. It "stands in contrast to modern political and psychological notions of human independence" (ibid.). The Gaia theory relies on symbiotic relationships and cooperation for survival in contrast to the neo-Darwinist view of life based on competition.

These principles appear in other emerging worldviews such as the *ecological worldview* which corresponds to the vision for a scientifically informed ecological agriculture (Callicott, 1990:45-46).

Agroecology as the enactment of the Gaia theory?

For agriculture and the food system, the mission is to transform the food system "into a viable subset of Gaia, which means approaching it as a holistic and autopoietic living system organized as a network of relations" nourishing people and ecosystems (Litfin, 2011: 427).

Callicott (1988:3) argues that "agroecology translate[s] this abstract new vision into a concrete agricultural vocabulary: The farmstead is regarded as an artificial ecosystem with a multiplicity of diverse plant and animal constituents interacting with one another and with environing natural ecosystems in complex and mutually supporting ways". The idea that "agro-ecosystems should mimic the biodiversity levels and functioning of natural ecosystems" lies at the heart of agro-ecology while "[s]uch agricultural mimics, like their natural models, can be productive, pest resistant and nutrient conserving" (Pimbert, 2015: 287). Principles for agroecology in the field (Nicholls et al., 2017) and in the food system (Gliessman 2016) express a systemic view of natural processes and agricultural practices.

In addition and fundamental to the agroecological approach is the understanding of nature as active participant in processes of production and change (Guzmán & Woodgate, 2015), which reminds of the co-creation of subject-object mentioned earlier. Further, the material and energetic sustainability – besides the economic efficiency- of agricultural systems emerges as a goal of agroecology (Guzmán & Woodgate, 2015).

Thus, for Callicott (1988:8), agroecology expresses a new paradigm for agriculture. Litfin (2011) does suggest that organic and agroecological farmers have adopted "a Gaian understanding of soil as a living web of symbiotic networks rather than an inert receptacle for chemical inputs". Rosset and Martinez-Torres (2013) suggest that this view of nature is held by the members of the agroecological movement in South America. Yet, we are not aware of any studies exploring western farmers' worldviews and confirming this theory.

Methods and case study

The role of agricultural narratives and metaphors

We start from the idea that language is constitutive of reality, rather than simply describing it (Escobar, 1996 as quoted in Guzmán & Woodgate, 2015: 13). This means that language such as metaphors and narratives structures agricultural paradigms and practices. Indeed, different metaphoric realms characterize industrial agriculture, indigenous and alternative agricultures or conservation.

Narrative and metaphor have much to do with ethics. Narratives help us develop and enact our ethical frameworks and think through various courses of action, depicting the consequences of our choices. Narratives are also morally binding (Sanford, 2011). In agroecology, we expect narratives to be rooted in the Gaia or ecological worldview. They may imagine agricultural practices that consider effects on multiple human and non-human communities (Sanford 2011: 284) and reunify their needs.

Case study and data collection

We chose to analyse narratives of agroecological farmers in Germany. The country has undergone a large-scale structural change in the last decades pressing conventional farmers to give up their farming or to get bigger (Domptail et al., 2018). At the same time, the share of organic farmers in Germany is lower than in its neighbors France and Austria. Yet, Germany seeks to be a leader in the climate change mitigation.

The case analysed is that of a small peasant farmers' association in Western Germany in a region domianted by large scale arable farming but adjacent to more hilly grassland landscapes. The association stands up for a socially equitable and environmentally sustainable agriculture and the establishment of conducive conditions. Its members include both conventional and organic farmers, with medium and small-sized farms. Anyone interested in supporting the aim of maintaining peasant farming, shepperds, horticulture and improve their lot may join. The association conducts political and agronomic events and supports the cooperation between farms and groups of citizens. It is also a cofounder of the European Coordination Via Campesina, an umbrella organization of peasant farmers taking part in an international fight for food sovereignty.

We follow a purposeful sampling strategy targeting both women and men farmers, conventional and organic farmers, as well as farmers with different farming systems such as arable, mixed, dairy system or horticulture. The sample and data consist of six in-depth interviews. The face to face interviews were conducted at the farmers' homsteads between october 2020 and January 2020. Farmers were first asked to narrate their farming life trajectories. Some of the topics mentioned were then depended using questions developed to address the heuristics detailed below. Additional facts about the farms and farming systems were collected additionally, when not mentioned before.

Only two farms, both organic, are analysed in the present version of this paper. Farm B is a mixte farm while Farm A is a grassland based cattle rearing farm with own slaughterhouse of 350 ha. Farm B is a mixte farm arable-cattle with 90 ha including 50 of arable cultivation. Both deploy considerable efforts to integrate biodiversity-foresting and animal-friendly practices in their farming system (see details in annex 1).

Qualitative reconstructive analysis

Reconstructive research seeks to investigate how humans mentally and thus practically shape the world they live in. Reconstruction means that we examine how social meaning is constructed by the application of linguistic means (signs and symbols) and how such social meaning is expressed in a documentary manner (cf. Kruse, 2014: 472). We apply an integrative basis procedure (*Integratives Basisverfahren*) by Kruse (2014), which aims to let the "data talk" in an inductive manner. Yet, due to the impracticality of a solely inductive analysis, the integrative procedure recommends the use of the heuristics of research objects (*forschungsgegenständliche Analyseheuristiken*) to structure and systemize the analysis openly. These heuristics can be understood as sensitizing concepts (cf. Blumer, 1954) which function as 'scanners' or interpretation guides for detecting the respective structures of meaning within the text.

We explore farmers' concepts of nature and the concomitant self-world relations by investigating five domains: (1) their understanding of nature and Man-Nature relations; (2) the profession of farming and its objectivity; (3) the nature of their knowledge; (4) human responsibility towards the global crisis and climate change; and (5) their relation to the political and food systems. Table 1 shows the research object-specific heuristics formulated for each domain.

Table 1: Research object-specific heuristics used as scanners in the text analysis.

Understanding of nature and human-nature (power) relations	How is nature described? (non-Western concepts of nature, e.g. Mother Earth, a home and living being or rather a source of resources?)
	How does the interviewed person position him/herself in relation to nature?

	How does the interviewed person perceive he/she reunifies her needs and the needs of nature through their activity? Is there a creative interaction between human activities and nature's productivity?
Work conception, professional identity and spirituality	Does the interviewed person mention spiritual aspects? What is the role of personal relationships to things in the farming system, that is, the significance of emotion, instinct and intuition in the farming activities?
	How does the interviewed person describe his/her professional identity in relation to other farming approaches?
	Is it rather about competition or cooperation? (De)growth?
Knowledge and system thinking	How does the interviewed person deal with the complexity of the natural system he/she interacts with? How does he/she perceive the role of scientific knowledge and technology? How does he/she deal with uncertainty?
	What is the aim of farm management (integrity and stability - or what other concepts are guiding principles)? Does the interviewed person make use of linear thinking or do they think in circles?
Responsibility	What is the perception of the interviewed person of his/her responsibility? At which scale (farm or world)? Do they hint at a "system" identity, such as planetary citizen or earth steward?
	How does the interviewed person perceive his/her (socio-ecological) agency with regard to the global environmental crises and especially climate change?
	How does the interviewed person describe his/her role in socio-political change? On what scale?
Embeddedness/connectedness vs individuality, and autonomy	How does the interviewed person position him/herself in the community? In society? in the world?
	How does the person relate to the higher systems it is embedded in, especially the political and food systems? Does the person strive for autonomy?
	Is the person's agenda at the farm or local scale? or is it connected with other people's agendas and aimed at enacting change on a bigger scale?
	How is globalism perceived and what are the perceived relationships between the global and the particular, the whole and subsystems?

Preliminary results and discussion: Worldviews in an agroecological farmers' union in Germany

The narratives are analyzed individually first and then compared.

Farm A. The farm in the global world.

The first most stricking feature of farmer A's worldview is the co-existence of a sense of respectful submission towards nature, due to human dependency on nature and the constraints it imposes on production processes, together with a strong sense of actively shaping nature, in the form of nature-like (*Naturnahe*) production systems. Although the farmer perceives that he curves nature according his will, he believes that his practices are the only positive way do to it because they maintain the qualities of nature which together build the life basis: air, water, soils and biodiversity. To maintain this lifebasis ("*Lebensgrundlage*") **intakt** is the central aim of the farming activity (Verbatim 1 and 2; in original transcript and language in annex 2).

" but (.) I don't LET eh eh eh nature to GROW as it in an ideal case would like to (1) but (1) Yes our lifeBASIS is eh here the INTERFERENCE in Nature we have to hum say it this way". Farmer A, §54.

„we are the FIRst in [OUR REGION], who have started again to (.) THIS EXTENT to MOW with the DOUBLEblade mowing machine (.) that means that we acquired a=a machine a MOWING technique (.) which is insect-FRIEndly and hum !YES! it involved many Risks=and also !MUCH! TROUble and EFForts TIMEwise and Financial hum (.) eh where we eh STILL believe today that THIS is the RIGHT thing to do !TO! pra-pracTICE the most POSItive possible !FORM! of agriculture" (Farmer A. § X).

The second main feature is the understanding of the farm as one element of the global social and ecological system and dynamics. The interaction with nature is understood in the anthropocen context. Indeed, the farmer perceives the role of humans in shaping nature as immense and at the same time endosses, in that role, the responsibility of shaping farming so that it addresses the global crises of social inequality and climate change. Thereby, those farmings practices are perceived as a communication, a form of dialogue, between the farmer and nature, as well as between the farmer and the world. For instance, the farmer perceives perceives certain aims and related practices as a political act towards a fairer world (Verbatim 3).

"YES what we (.) in addITION try to do is to MANAGE the PAStures (1) so that eh (.) okay this is now also political- BUT it just came to my mind YA eh that we try to build build UP our HUMUS that means to BIND CARBON Dioxyde from the air" (farmer A, §28).

Local marketing is also perceived as a way to avoid unfair competition with the global south (Verbatim 4).

[Industrial agricutlure] "attempts with SMALLEST POSSIble WORK use to produce the highest OUTput (.) THIS resULTS of course from the DISCREPANCY (.) between SIGNIFICATION [orig. WERTigkeit] of the FOOD and our general wage level (.) but it also induces that we (.) eh=eh OTHER foods (.) primarily things that are=are=are WORKintensive in their production (.) WE HAUL them from Other regions of the world" (Farmer A, §47).

Farm B. An island in the midst of desolation

The most stricking feature in Farmer B's worldview is the representation of nature as perfect. Nature is the embodiment of God, is surprising by its powers and wonders and is fundamentally associated with two key attributes of diversity and complixity. Through a "reverential" attitude and "fascination", the farmer takes nature as as inspiring role model, which she uses to create habitats or spaces for living ("*Lebensraum*") for humans and other species, today and tomorrow. She perceives her exchanges with nature as a "give-and-receive" relationship where she contributes to sustain or increase the lifebasis and gets in return a haverst and a meaningful job. She describes this as a tightrope walk (*Gratwanderung*), a challenge in order to maintain a certain balance (verbatim 5):

"So: it is of course eh also a TIGHTrope walk because eh ya OTHERS SAY (.) well then let the nature completely ALONE so (.) mhm to !GROW! as IT WISHES (.) mhm but I SEE this again NOT this way because when then a plot isn't used AT ALL, then eh it is not always BETTER so you find the highest humus CONTENT [orig. AUFBAU] under PASTURES grazed by CATTLE (.) and where many different GRASSES grow and FLOWERS and all those SPEICIES they are only there when someone makes HAY and also hm MOWS (.) cuts the grass and (.) takes it AWAY so eh (1) it (.) is always about needing to maintain the EQUILIbrium " (Farmer B §15).

Second the farmer understands the farm as an element of the living landscape, which acts as an organism (Verbatim 6).

"just HOW the landscape ehm (1) just NOURISHES itself from the construction of PONDS and irrigation systems that are integrated in the landscape (.) mhm (1) that also EACH corner nearly EVERY plot has its VERY special PROPERties that one should eh SEE and use". Farmer B §9.

In describing the landscape as a place of desolation (large scale monocultures), she perceives her farming activity as a counter-action, and in fact a **nature protection** act. For instance, she uses flower strips and mowing techniques, which support insect and small fauna diversity and chooses her crop rotation according to surrounding cultures to ensure an ecological stability in the landscape (Verbatim 7):

"When you LOOK at the landscape, you see (.) in fact !DESOLATEDNESS! (.) so you see insanely large areas without diversity eh (.) cultivated with one crop only (.) no hedges (.) these are things (.) I try to somehow COUNTERACT (.) so I try most of the time to CULTIVATE MIXTURES of crops (.) FLOWERIng strips surround EACH of my FIELD!EDGES! (mhm) at the BORDER to the next FIELD (.) I try to cultivate crops that flower when NOTHING flowers in the landscape (.) ehm yes (.) I (.) actually do (.) quite some (.) nature PROTECTING (.) or nature conservation eh ya." Farmer A.

She perceives a responsibility to protect other species in this context and has an emtional bond with them.

Equal relationship with nature: good, fair and fear

The human-nature relationship described is one of respectiful partnering and egalitarianism.

A first common attitude towards nature is amazement. Nature, in its powers, its complexity - web of linkages and complementarity - its diversity, is perceived as marvelous and beautiful. The amazement suggests that farmers observe nature and its works (functioning) very closely – this observation of nature's work is one essence of a certain humility, or recogntion that nature has its own path and powers. The observation is also at the basis of the dialogue with nature.

In parallel, one important element of the nature-farmer relationship is a very developed understanding of the earth, landscape and farm as nested and complex systems. This is a key guideline for the farming practices and farm design. At the same time, the web of complexity is related to fears: because chains of causalites are complex, consequences can be numberous. Biodiverity loss, climate change and social unrest were feared consequences of the system behavior of Earth.

These two elements enable a third dimension of the nature-human relationship: the usage/crafting dimension. While farmers depend upon and admire nature, **they shape it** so as to create a life basis and life spaces supporting both humans and other species needs. Farmers feel particularly empowered to make the choice of "positive" practices that enable them to make the "good" decisions towards a nurturing land use. Importantly, they perceive the beauty of nature in complex and diverse **man-made** (agroecological) agricutural systems.

Local farming for global consequences

Perhaps the most striking sense of citizen responsibility taken up by the farmers is that they wish to preserve nature as a life-basis and a space for life for all species, for future generations and for all because they want to help save the world. They do so through great expenditure of time, effort and money.

The two interviewfurther address two scales of acting responsibly. First at the context of the landscape, the farmer strives to provide islands of biodiversity to sustainable life across the landscape. Second, at the scale of the earth, farmers feel that their actions are connected in a telecoupling manner with local happenings elsewhere (e.g. in the global south, in the atmosphere) and do act accordingly by designing farming systems able to address many short shortcoming of the dominant industrial agriculture model. This desire to address current global issues is further represented in the vocabulary used by Farmer A which he interstingly co-opts from the productionist paradigm and applies to agroecological practices (“highly productive”, “intensive production”, “rational thinking”).

The “Lebensraum”

The life-basis concept, framed in the interviews as soils, water, air and biodiversity and complexity, appears as a key concept to reconcile views of nature as wild versus tamed. This concept provides a new aim for the agricultural activity, based on the idea that agricutlure can be the crafting act of turning nature into a life-support system for multiple species. It transcends the western utilitarian view of nature as conserved or exploited to come close to the concept of environmentalism of the poor (Martinez-Alier, 1997), characterised by the perception of dependency on nature. This suggests that, perhaps, agroecological farmers are developing an environmentalism of the peasant, but a peasant of the global world, very far from the romanticized view that peasants are cutting themselves from the modern world and its challenges.

Conclusions

Alternative worldviews to the dominant Western worldview are essential to improving the food system and addressing climate change and other environmental crises because worldviews shape (agricultural) actions. Agroecology claims to be different from all forms of present modern agriculture systems and to have the potential to address the global environmental crisis and climate change because it is based on a different worldview; one that reflects a decolonized and systemic an-Nature relationship.

The current dominant Western worldview is based on a reductionist approach to nature and analysis, and on the idea that we can control nature. It has fostered an extractive form of modern agriculture which alienates humans, and farmer in particular, from an experiencial communication and interaction with nature. Integrative and ecological worldviews, as well as the Gaia theory are being developed by science in an attempt to reconcile humans’ and Earth’s needs. These address the human consciousness about their relationship to nature and they attempt to reunify mind and matter so as to depart from a mechanistic approach to natural resource management. Agroecological farmers claim to operate on such a decolonized relationship and a systemic understanding of nature. Our analysis of narratives from agroecological farmers in an arable fertile region of Germany shows that farmers have adopted Gaian worldviews seing the farm as an element of the landscape organism and of the earth social and ecological organism. Under the new worldview, the farmer, his motivation and his operating territory matter. Production does not happen alone but rather in a territory and as the result of the interaction of actors among themselves and with their environment. This worldview enables farmers to indeed enact values which they share and that address their role with regard to the global environmental crisis.

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Annexes

Annex 1: Description of the Case Study Farms

(Only the two farms used in the results section till 13.02. 2020; will be updated to 6 or 7 farms in a complementary version of this paper).

Farm A	(anonymous)
Size (ha):	330 ha
Ownership status:	1/3 own land, 2/3 leased land; bought the land and the farm together with his wife 20 years ago
Labor force:	3 adults (himself, his wife, and a partner), his children
Crops:	Arable farming on 20 ha in cooperation with another farm
Pasture and grassland:	310 ha
Woodland	none
Unused area:	2-3 ha fallow land
Number and species of animals:	Cattle (250-300: 90 Suckler cows, 90 One-year-olds, 90 Two-year-olds)
Meat business:	yes
Certification:	Naturland
Unions/clubs/associations:	Two peasant farming and one nature conservation associations
Gender:	male
Age:	Between 40 and 50
Education:	graduate
Experience as farmer	40 years total, 20 years on own farm
Greatest motivation:	Family
Greatest challenge:	Family
Farmer A started without his own farm and built up the present farm from scratch together with his wife in Germany about 20 years ago. They built their own slaughterhouse in order to be able to accompany the animals to their death and reduce their stress. As part of an integrated pasture management, the cattle spend 10 months a year outdoors on the pasture to maintain medium-high grass in order to increase soil fertility and to ultimately store air CO2. The cattle is fed without external inputs. The farmer is further concerned about biodiversity loss and therefore acquired a cost- and maintenance-intensive yet insect-friendly double blade mower. The family bears all the work on the farm and shares the enthusiasm for an environmentally and socially compatible small-scale agriculture with local and direct marketing, an international perspective and political engagement.	

Farm B	L. G.
Size (ha):	90 ha
Ownership status:	15% own land, 85% leased land together with a partner farm
Labor force:	3
Crops:	50 ha. Wheat, rye, barley, millet, pea, bean, grain fennel, sugar beet, various intermediate crops, sunflower (next year), buckwheat. Products of market gardening/ Orchard meadow: Sweet cherries, apples (apple juice); nuts, mirabelles and others
Pasture and grassland:	40 ha
Woodland	none
Unused area:	None (even though flower strips and hedges officially count as fallow land, but farmer considers them as tillage and landscape elements)
Animals:	Suckler cow herd (red mountain cattle) and 3 horses
Meat business:	Yes, but extensive; cattle rather used as caretakers of the landscape and forage processors
Certification:	Demeter
Unions/clubs/associations:	Several associations but active in one peasant farming association.
Gender:	female
Age:	Between 30 and 40
Education:	graduate
Experience as farmer	10 years, 6 years with own farm
Greatest motivation:	Her children
Greatest challenge:	Short days and having the strength to do what you want to do
L. G. started organic farming six years ago together with her husband in Center-West Germany. She is interested in interdependencies both on a small and large scale and completed training in permaculture in Australia. Questioning common practice in agriculture, she incorporated a high number and diversity of landscape spatial and temporal elements such as hedges, flower strips and animal friendly mowing dates on the whole of her farm. She is the president of the peasant farmer association. This year, she plans to offer seasonal gardens to bring agricultural activities, knowledge about food and its production closer to the people and to offer place for community and social interaction.	

Annex 2: Verbatim original transcripts and language.

Verbatim 1: mhm] die=die aber (.) aber die=die=die naTUR (.) nicht so LÄSST wie se EIgentlich WACHSEN würde so gern ma des im idealfall gern tun wöllte (1) aber (1) JA unsere lebensGRUNDlage is äh sch- <<Telefon klingelt>> IS hier der EINGRIFF in die naTUR des muss mer [mhm] so sagen" (Transkript Farmer A - Final, Absatz 54)

Verbatim 2: „wir jetzt die ERsten in HEssen (.) die angefangen ham wieder mit (.) in DEM UMFANG mit nem DOPPELmessermähwerk zu MÄhen (.) das heißt wir ham uns ein=eine maschINe angeschafft=eine MÄHtechnik angeschafft (.) die inSEKtenschONend scho- äh MÄht (.) u:nd=ä:hm (.) !JA! was mit viel RIsiken verbunden WAR=auch mit !VIEL! (1) ÄRger und AUFwand ZEITlich und FInanziell [mhm] (.) äh: wo wa aber jetzt doch äh IMmernoch der überzeugung sind dass DAS (.) das RICHtige is (.) !UM! (2) eine möglichst POsitive !FORM! der landbewirtschaftung zu prak-praktiZIERN (.) (Transkript Farmer A – Final)

Verbatim 3: „JA was wir (.) darüber hinAUS versuchen ist des GRASland SO zu beWIRTSCHAFTEN (1) dass äh:m (.) nagut des hat jetzt mit politisch n- ABER des fällt mir grad so ein [JA] äh dass wir=dass wir versuchen HUMUS aufzuBAUEN das heißt auch KOHLENstoff aus der luft zu BINDEN (.)" (Transkript Farmer A - Final, Absatz 28).

Verbatim 4: Industrielle LW „versucht mit !MÖG!lichst WENig !ARBEITS!einsatz MÖGLichst hohen AUS-OUTput zu erzeugen (.) DAS resulTIERT natürlich aus der DISKREPANZ (.) zwischen der WERTigkeit von den LEBENSmitteln und unserm allgemeinen lohnnivEAU (.) führt aber auch DAzu dass wir (.) äh=äh ANDERE lebenmittel (.) vor allen dingen SOLche die=die=die ARBEITSintensiv erzeugt werden (.) UNS aus ANdern regionen der welt ähm (.) HIERHER holen." (Transkript Farmer A - Final, Absatz 42)

Verbatim 5: „also: [ja] es is natürlich äh=auch so ne GRADwanderung weil äh (.) ja ANDERE SAGEN (.) dann muss man die natur ja ganz in RUHE lassen ver-also (.) ne [mhm] für SICH !WACHSEN! LASSEN (.) [mhm] aber des SEH ich dann wiederum NICH so weil wenn man dann (.) ne fläche GAR nich mehr bewirtschaftet dann ähm (2) is das nich unbedingt viel BESSER also den höchsten humusAUFBAU hat man (.) unte:r WIESEN die mit RINDERN beweidet werden (.) [mhm] und wo ganz viele GRÄSER drauf wachsen und BLUMEN und die:se ganzen (.) ARTEN die gibts nur wenn jemand da HEU macht und des gras auch m=MÄHT (.) [mhm] schneidet (.) und wieder WEGfährt also=äh (1) des äh (.) is immer so des (1) GLEICHgewicht was eingehalten werden muss" (Transkript Farmer B, Absatz 15)

Verbatim 6: „DA gabs auch ähm (1) !EINIGE! schlüsselerLEBNISSE WIE einfach die land (.) SCHAFT sich auch ähm (1) ja NÄHRT einfach durch anlage von TEICHEN und bewässerungssystemen die man dann in der landschaft integriert (.) [mhm] (1) dass doch auch (.) JEDE ecke quasi JEDER=jede fläche seine GANZ spezielle EIGENschaft hat die es äh zu SEHEN und zu nutzen gilt" (Transkript Farmer B, Absatz 9)

Verbatim 7: „wenn man (.) in die LANDschaft SCHAUT (.) sieht man (.) eigentlich ne große (1) !ÖDNIS! (.) FAST (.) also man sieht wahnsinnich große flächen ohne vielFA:LT äh (.) einfach mit einer kultur bestande:n (.) kaum hecken (1) des sind so dinge (.) da versuch ich irgendwie GEgenzuSTEUERN [mhm] also ich ähm (.) versuch meistens pflanzen im geMENGE anzuBAUEN (.) BLÜHstreifen sind am JEDEM meiner FELD!RÄNDER! [mhm] zum- an der GRENZE zum nächsten ACKER (.) ich versuch kulturen anzuBAUEN die blühen wenn sonst !NICHTS! blüht in der landschaft (.) [mhm] (.) ähm (2) ja (.) ich (.) mach schon (.) en zimmich ähm (1) naturSCHÜTZENDE (.) ode:r naturschutz äh=ja: (.) wie sagt man denn (.)" (Transkript Farmer B, Absatz 11)

CONCEPTION OF LOCAL CARBON MARKETS CONNECTING FARMERS AND COMPANIES: SOCIO-ECONOMIC OUTLINES OF INNOVATIVE SCHEMES

Thareau, B.[a], Seyni, N.[b], Coisnon, T.[c], Dupraz, P.[d]

[a] ESA, UP LARESS
[b] INRA, UMR SMART-LERECO
[c] Agrocampus Ouest, UMR SMART-LERECO
[d] INRA, UMR SMART-LERECO

Introduction

Various environmental policies promote the implementation and maintenance of hedgerows such as those within the framework of the agri-environmental contractualisation of the common agricultural policy (CAP), or planting support programmes run by local authorities. In context of the rise of "market-based policies", voluntary carbon markets appear as a possible way of valuing environmental carbon storage services. However, agriculture makes a modest contribution to compensation projects: 22% of the respondents surveyed by Tronquet (2017) say they compensate through agricultural projects, while 38% of the respondents would like to do so.

In the West of France, one of the important levers of carbon storage is the maintenance of hedgerows. Indeed, the French environmental public agency (ADEME) has identified hedgerows as one of the various ways to mitigate greenhouse gas emissions, particularly through carbon sequestration, in addition to other ecosystem services, including preventing erosion, the regulation of water flows and the improvement of biodiversity and landscape quality. This importance is endorced in the greater western region of France, particularly in the Pays de la Loire and Brittany areas where hedgerow conservation is paramount (ADEME, 2015). These claims in regard to the importance of hedgerows for carbon sequestration are also supported by research conducted on hedgerows, which has shown that the carbon stocks in soils observed in the vicinity of a hedgerow are higher than those observed in cultivated plots (Follain et al., 2007; Lacoste et al., 2015). Three reasons were given: (1) carbon inputs from the hedgerow's perennial vegetation are greater than those for annual crops, whose biomass is often partly exported; (2) deep mineral soil horizons below the hedgerow have a significant organic matter content relating to significant biological activity in the entire root depth of trees; (3) in situations subject to erosion, hedgerows can limit soil and carbon loss associated with eroded particles. Recent research measured the storage potential of hedgerows in the West of France (Pays de la Loire and Brittany). The research confirmed the estimations previously proposed by Pellerin et al. (2013) of approximately 0,5 $TeqCO^2$/100m/year for mixed hedgerows (in aerial, roots and soil compartments). This level of storage varies greatly in relation to the plant species composition of hedgerows, the age of hedgerows and the level of initial carbon stock in the soil (Viaud and Gautier, 2019). However, despite previous public and local policies intended for the maintenance of hedgerows, hedgerow length is still decreasing. The challenge of this study is therefore to find new ways to promote the maintenance and creation of hedgerows by farmers. Our project, therefore, examines the conditions for the development of volontary local carbon markets as a new way to enhance hedgerow maintenance and to mitigate climate change.

Carbon markets: singular schemes in agroecological transitio

Our project thus begins with an ambition to introduce new ways of enhancing hedgerow management in rural territories of Western France. But this ambition is far from new. As McCollin (2000) states, concern regarding hedgerow maintainance arose in the early part of twentiest century: following the American dustbowl episode, the focus of early conservation measures was often on the soil (and the microclimate effect of hedgerows as shelterbelts). Biodiversity started to become a key issue supported by conservationists in the 1970s. Meanwhile, a variety of arguments were discussed such as the visual benefits of hedgerows, and more recently the agronomic, zootechnic and economic benefits regarding grass and crop production or animal welfare. The role of hedgerows in carbon sequestration is of recent interest. If the concern for climate change mitigation emerged at the end of the last century, the identification of the maintainance of hedgerows as a key landscape component in climate change mitigation only emerged recently: in France, the publication of an INRA study in 2013 on the effect of agricultural practices on climate change mitigation has been a starting point. The authors estimate that the development of hedgerows on agricultural land could allow for 1.2 MTeqCO2 to be stored by 2030 in France, placing this measure at 10th rank of the 26 measures studied (Pellerin and Bamière, 2013).

At the same time, public schemes concerning the hedgerow management issue have evolved. Until the 1990s, in France as in other European countries, the state assigns rural management strategies to landowners and farmers (McCollin, 2000; Thareau and Billaud, 2014). In the 1990s, European legislation invested environmental issues, demonstrated by the establishment of the first agri-environmental measures. In France, the 2000s were a period of reinforcement of the role played by local communities in the animation of territorialized environmental projects (Thareau and Fabry, 2013). It was at this time that the first territorial climate projects emerged (2004). In 2009, the French State created a pivotal role for large local authorities with regard to local environmental policies: it extended their area of competency into the field of climate and biodiversity (Bertrand, 2013). However, local authorities have not yet integrated carbon offsetting into their policies to fight climate change (ADEME 2016).

In this context, carbon markets may be a unique mechanism for agriculture, particularly because they are a market-based instrument which could instigate private corporate investment, particularly in a political landscape dominated by a contractual logic between the French State or Europe and farmers (for example, AEMC for maintaining the hedgerows), public investment (such as, planting subsidies from local communities), or coercitive policies to protect hedgerows (for example, urban planning).

Research suggests that environmental innovations in the agricultural sector have been embraced, mainly as a result of CAP (AEM) Agri-Environmental Measures and subsidization. Research demonstrates that farmers' willingness to participate in agri-environmental schemes varies according to factors such as the duration of the contract, time spent on non-operational aspects, the level of payment, technical assistance, flexibility in relation to the requirements of the scheme and flexibility with regard to the area included in the project (Ruto et Garrod, 2009; Espinosa-Goded et al., 2010; Christensen et al., 2011; Siebert et al., 2006). The involvement of companies in an environmental scheme, have been studied in relation to corporate social responsibility (CSR) measures. Organizational factors influence a company's commitment decision: size of the company, age, sector of activity and degree of innovation. Individual issues (gender, age, sensitivity and emotional commitment of the manager) are also deciding factors when it comes to adhering to a CSR policy (Cabagnols et Le Bas 2006; Labelle et St-pierre 2010; Spence et al 2007; Gherib, 2006). Some authors interpret a company's commitment to sustainable development or CSR schemes as an attempt to enhance their image and gain a more competitive advantage (Cabagnols, 2006). Others seem to act for ethical reasons, environmental image or to anticipate future regulations (Chenost et al, 2010).

Some research explores more innovative schemes and questions the effects of these schemes on stakeholder involvement. Various forms of payment for ecosystem services are explored. They demonstrate that the conditions of some schemes do influence stakeholder involvement: the strong involvement of an intermediary and trusting relations within the farming community (Mariola, 2012). Schirpke et al. (2017) show that to succeed, these schemes should benefit from public support, and involve human resources to conduct a participatory process. This process should be inclusive for all types of stakeholders, to understand and consider stakeholders' values and objectives, to identify local dynamics, and to eventually, produce trust. Lockie (2013) underlines that the success of schemes such as cap and trade regimes in GHG emissions depends on the legitimacy of the scheme : the sucess relies on a clear understanding of the ecosystem services in question as well as a transparent, robust and broadly accepted institutional and regulatory framework for monitoring and trading.

This review underlines the role of contract or scheme characteristics in the involvement of stakeholders. Our project focuses on a proposition of volontary carbon markets. Such carbon markets relating to agriculture are not yet established in France, and therefore, the commitment from companies, farmers and local authorities remains uncertain. Our research aims to specify the outlines of such schemes to favour stakeholders involvement.

Method

Our research focused on three categories of stakeholders - farmers, companies and local authorities - regarding the objective and conditions of participation in a carbon market. For this, we conducted in 2018 and 2019 a survey of 88 respondents in 3 territories of Western France (22 companies and 45 farmers and 21 local authorities) to measure and explain their preferences. The results of this survey were consolidated into 3 focus groups comprising businesses, local representatives and farmers.

Measuring relative preferences for an innovative scheme

To enable respondents whose understanding of the carbon sequestration potential of hedgerows is minimal, to invest into little-known carbon market schemes, we chose : i) to provide information on the carbon sequestration potential of hedgerows and carbon market schemes before and during the interview; and ii) to propose scheme scenarios and to test respondents' preferences for possible alternatives.

Three different questionnaires were designed and submitted to the three categories of respondents. Each questionnaire was structured into four sections: (1) the characteristics of the respondent and the entity (farm, company, community), their relationship to the environment and climate mitigation strategies, (2) their knowledge of hedgerows and the carbon market, (3) their preferences towards different possible systems, evaluated on the basis of a set of cards based on the Discrete Choice Experiment (DCE)[57] method, and finally (4) the reasons for their preferences according to the different attributes of the system. The first three themes were mainly addressed through closed questions, the fourth was mainly addressed through open questions.

Several analytical methods were used to process the data collected. They consisted of statistical analyses of quantitative and qualitative data (AFCM, discrete choice methods) and qualitative analyses of responses to open-ended questions.

A sampling of respondents affected by hedgerows or the climate

The aim of this sampling method was to test the possibility of creating a carbon market and its potential characteristics, even though the respondents were more inclined to engage in the scheme.. We,

[57] A method introduced by Louvière (1983) in environmental economics to assess the value of a property via its attributes or characteristics.

therefore, constructed reasoned sampling based on two criteria for farmers (belonging to the study areas and prior participation in bocage or agri-environmental projects), two criteria for companies (link to the target territories, and commitment to a diagnosis or carbon offset approach), and two criteria for local authorities (link to the target territories and field of activity: agriculture, climate energy or environment). We sought to favour respondents who had initiated climate or agro-environmental initiatives in these three categories of respondents.

Table 1: *Distribution of the sample by study area*

Territories	Farmers	Companies	Local Authorities
Pays des Mauges	18	9	4
Pays du Roi Morvan	16	2	5
Pays de la Vallée de la Sarthe	10	1	3
Outside territories	1	10	9
Total	**45**	**22**	**21**

The farmers surveyed are mainly male (91%), aged around 50 years old with education levels varying between secondary school and higher education. Farms have an average agricultural area (UAA) of 107 ha. A third of the respondents have obtained organic certification and more than 77% of them have already participated in other environmental schemes (AEM, tree planting program etc.). This sample therefore corresponds to farms larger than the average in Western France (about 65 ha in Brittany and Pays de la Loire in 2017), and farmers more involved in environmental schemes (about 8% of farms are AB certified in these same regions in 2017).

The sample of companies is dominated by males (68%), relatively young (41% are under 40 years of age) with high levels of education (Masters degree level represents 68% of the respondents). The companies surveyed are divided between SMEs (nearly 41% or 9/22), FTEs (36%) and large companies (22%). There are no microenterprises with less than 10 employees. This sample therefore over-represents medium to large companies at the expense of companies with less than 10 employees. Indeed, at the national level, 96% of companies, excluding financial activities and insurance, are microenterprises, while large companies represent less than 1% of them (Insee, 2017). More than 80% of the companies surveyed say they have carried out a diagnosis of their greenhouse gas emissions and undertaken actions to reduce their carbon footprint.

The sample of local authorities is composed of 10 elected officials and 11 agents. They are in charge of energy, sustainable development or climate issues (33% of them) or involved in agricultural and agri-food issues (33%). They are elected or agents of the intermunicipalities of the survey areas, of the municipalities, or for a third of them, of other communities (nearby agglomerations, departmental councils). They are mainly male (71%). The levels of education are generally high since a Masters degree represents more than half of the sample. More than 60% of the local authorities surveyed did not carry out a greenhouse gas (GHG) emissions diagnosis, but 60% of the local authorities carried out a bocage diagnosis, which illustrates the interest shown in bocage hedgerows.

Survey areas characterized by the density of hedgerows, the pre-existence of hedgerow projects and the importance of livestock farming.

The three territories surveyed are included in the two regions of Brittany and Pays de Loire. These territories were chosen for their determination on energy and climate transition issues, which is reflected in the fact that these three have set up a Climate Local Policy, but also for their longstanding work on bocage and carbon storage. Agriculture is very important in these three rural territories with important production capacities. Production is generally oriented towards livestock (mainly dairy farming), poultry and pig farming (Table 2).

Table 2*: Summary of territory characteristics studied*

Territories	Pays des Mauges	Pays du Roi Morvan	Pays de la Vallée de la Sarthe
Number of residents	121 000	26 500	78 000
Surface Area (km²)	1 315	763	1 104
UAA (utilized agricultural area) in ha	141 5980	43 801	413 900
Hedgerows length (km) (in 2011)	10 343	4 314	5 098
production orientation	Livestock farming	Livestock farming	Livestock farming
Policies in place	-Circular economy - Territorial Climate-Air-Energy Plan, initiated in 2003 -PAT (territorial food program)	- Territorial Climate-Air-Energy Plan initiated in 2010 - Hedgerow plantation programs (2003-2006 and 2011-2013)	- Territorial Climate-Air-Energy Plan initiated in 2009 - CEP (Shared Energy Advisor)

Results

High commitment linked with different views of local carbon markets

The first challenge of our survey was to measure the interest of the respondents in a local and voluntary carbon market scheme. Although we had chosen respondents a priori concerned with maintaining hedgerows or with climate change issues, (which would tend to increase interest in our proposal), many of these respondents had already invested in hedgerow plantations or climate change systems (more than three-quarters of them). It was therefore, far from certain that they would be interested in testing a new type of mechanism.

After describing the characteristics and main features of a local carbon market for hedgerows, we asked them: *"Would you be willing to engage in this type of scheme?".* Nearly 80% of respondents want to get involved, regardless of the type of individuals involved.

The motivation behind the respondents' commitment highlights the signification of such a scheme Local authorities see this scheme as a way to increase support for hedgerows preservation. The multiple advantages of the scheme, particularly in terms of ecosystem services (preservation of biodiversity and landscape quality, and therefore quality of life), appear to influence their commitment. Local authorities also underline the importance of these schemes in relation to stakeholders who are encouraged to engage in climate and environmental issues, and in order to generate added value for the territory itself. These respondents more often project themselves as intermediaries in the market, only a third imagine themselves as intermediaries and buyers of carbon credits. For companies engaging in a carbon offset market, this allows them to be part of a virtuous environmental approach and to establish their territorial anchorage, in addition to economic interests and positive spinoffs in terms of the company's image. Farmers mainly see it as an opportunity to better remunerate hedgerow maintenance, which many already do. Some are also motivated by environmental and climate ambition, by the possibility of increasing their social recognition, and to improve their hedgerow management. Respondents who are hesitant or unwilling to engage in this scheme mainly say they lack information on the scheme (cost, relevance, interests, actors involved) in order to be able to give their opinion.

A shared ambition to combine different environmental benefits: carbon storage, biodiversity, water quality, landscapes.

The objective in these voluntary markets would of course be carbon sequestration. However, the definition of this objective can be clarified according to different dimensions, including the consideration of environmental co-benefits and the inclusion in the contract of requirements concerning the practical modalities of carbon sequestration.

We have chosen to measure respondents' preferences for different qualities of carbon credits through three indicators:

Affiliation to environmental co-benefits was measured by assessing the preferences of respondents between two types of hedgerow: mixed hedgerows are presented as hedgerows that moderately store carbon, but generate multiple environmental co-benefits (biodiversity, landscape, water purification, erosion control) and coppice hedgerows are presented as those which store more carbon but generate fewer environmental co-benefits.

- The duration of farmers' commitment (5, 15 or 30 years),

- The proportion of hedgerow length managed by the farmer: either all the hedgerows present on the farm, or part of his hedgerow length, with the possibility of changing them (moving, grubbing up, replanting).

Our survey shows a strong preference, from all types of respondents, for hedgerows with environmental co-benefits. 71% of respondents say they prefer this modality when only 11% say they prefer coppice hedgerows. This preference is supported by the statistical analysis of the DCE (Discrete Choice Experiment). For all types of respondents, this preference is explained by the perceived importance of other environmental issues: biodiversity in particular for companies, water in particular for local authorities, aesthetics and biodiversity for farmers. Preference for mixed hedgerows is also linked to the desire to maintain existing types of hedgerows on farms or in the area and to implement previous hedgerow projects or policies (communities, farmers). Finally, farmers are interested in the economic co-benefits associated with mixed hedgerows: wood production and valorization.

Preferences are more heterogeneous with regard to the duration of the engagement and hedgerow length to be managed. A small majority of respondents prefer a 15-year commitment period, with very mixed responses for hedgerow length. We can thus distinguish four types of preferences concerning the contract objective.

- **The whole length of a mixed hedgerow:** The aim here is to support the creation or improvement of mixed hedgerows, during a 15-year contract which covers the entire length of a farmer's hedgerow. This contract is in line with previous projects and practices. For these respondents, it is a question of proposing a contract that is consistent with the ambition of storage in the medium or long term, with hedgerow maintenance cycles. The commitment of the entire length is a guarantee of maintaining hedgerows (for local authorities) and securing the scheme (for companies), whose main fear is that farmers will continue to pull up trees. Farmers consider that it is coherent and interesting to think globally about the management of hedgerows on their farm, and that the commitment of the entire length is a guarantee of administrative simplicity.

- **Flexibility concerning mixed hedgerows:** here too, it is a question of giving priority to the creation or improvement of mixed hedgerows, but this time the respondents prefer 5 or 15 year contracts and give priority to the possibility for farmers to lease only part of their hedgerow length or to be able to move the committed hedgerows. The aim is to enable farmers to commit themselves in stages, to test the scheme, but also to adapt it to changes on their farm, by allowing adjustments to the contractualised hedgerow length and by maintaining a certain freedom to manage their entire hedgerow length. This is the preferred contract for all categories of respondents. However, companies highlight the importance of implementing precise control over hedgerow length developments.

- **Strong commitment regardless of the type of hedgerow:** respondents who prefer a long contract tend to also prefer a total commitment of the hedgerow length. Farmers who prefer these contracts also want to create new hedgerows and not just improve on or manage existing ones. Respondents think it would be desirable to propose a highly engaging scheme to strengthen its credibility (companies, local authorities) and its impact in the fight against climate change. Farmers also underline that they do not plan to remove hedgerows, with or without contractualization. Finally, some mentioned the environmental challenge of maintaining ecological continuity, which justifies the use of the whole hedgerow length.

- **Partial coppicing:** this fourth type of contract is the only one that favours coppice hedgerows, over commitment periods of 5 or 15 years and management of only part of thehedgerow length. For these respondents, the challenge of rapidly storing carbon is a priority and in this respect justification lies in supporting the most efficient hedgerows only. For farmers, it is also the contract that appears to be the most profitable. In any case, the flexibility of the length of hedgerow system used makes it possible to adapt to the challenges facing farms, but also to other measures to fight climate change that could be developed, such as land exchange.

For the three variables tested, the level of indecision (cumulative non-response and "don't know" responses) is high, particularly for the sub-population of local authorities. Respondents explain that they do not feel competent to arbitrate, or that they consider that farmers should be given the choice to adapt as best they can to their situations. It also concerns respondents who are not interested in the scheme (farmers, local authorities).

Tab 3: Preferences for contract types according to the respondents surveyed

	Farmers		Local authorities		Companies		Total	
	Eff.	% Obs.	Eff.	% Obs.	Eff.	% Obs.	Eff.	% Obs.
The whole length of a mixed hedgerow	16	36,40%	2	10%	3	13,60%	21	24,40%
Flexibility concerning mixed hedgerows	15	34,10%	10	50%	8	36,40%	33	38,40%
Strong commitment regardless of the type of hedgerow	6	13,60%	1	5%	4	18,20%	11	12,80%
Partial coppicing	2	4,50%	2	10%	4	18,20%	8	9,30%
Undecided	5	11,40%	5	25%	3	13,60%	13	15,10%
Total	44	100%	20	100%	22	100%	86	
p-value = 0,13 ; Khi2 = 12,41 ; ddl = 8,00								

These preferences are different according to respondent type (Tab3). In particular, it should be noted that company preferences are more dispersed than for the other cate gories and that more community respondents are willing to give farmers some flexibility.

Four preference categories relating to the socio-economic attributes of the scheme

We hypothesized that the conditions under which the voluntary carbon market mechanism was organized influenced the respondents' desire to engage in it and their willingness to pay or receive. We therefore asked the various respondents to give us their opinions on a set of possible scheme characteristics: the nature of the intermediate actor within the market and the methods of control, but also traceability (in a "traced" market, buyers identify carbon as coming from a group of farmers in a given area, and in return, these farmers know their buyers and each of the stakeholders), the possibility of benefiting from technical support, the nature of carbon credit certification and finally the way the price is constructed (indexed to another carbon market, at hedgerow maintenance cost or not indexed).

Respondents generally agree on the interest of implementing a traced market. 71% prefer this modality compared to only 8% who prefer an untraced market. Local authorities and companies underline the importance of traceability in creating links between buyers and sellers, facilitating the monitoring and control of the action and making it possible to communicate with employees or customers of companies, by directly involving farmers. For farmers, this facilitates local recognition of their commitment to climate change issues. Some farmers prefer an untracked market. In this case, they consider that traceability is unnecessary since, on the contrary, the aggregation of carbon credits at a regional or national level makes it possible to simplify the scheme, reduce transaction costs or facilitate access to the market.

For the other characteristics, the preferences appear more contrasted, we distinguish four desirable profiles:

Local development system. The voluntary market would strongly involve a local organization as a central actor in its governance. Control could mobilise buyers and sellers through a participatory guaranteed system. As the aim of the scheme is to support better management of hedgerows, it seems important here that there be technical support and that the price paid to farmers be indexed to the costs of maintaining the hedgerow.

- OTC contracts between companies and farmers in a simple and inexpensive system. To implement a local carbon market, it must be simplified. Systematically, these respondents prefer uncomplicated forms of governance (no certification, no technical support), the preference is oriented towards a direct contractualization between companies and farmers and for this a link to a private intermediary is appropriate.

- National aggregated environmental public policy scheme. The local roots of the market and its traceability are of little importance to these respondents. The focus is on ensuring the implementation of reliable and credible storage practices, including certification and technical control. The State appears to be the right intermediary for this mechanism.

- A local supply traced within the international carbon market. For these respondents, the voluntary carbon markets resulting from hedgerows must be able to integrate into international markets. To do this, the price must be indexed to international prices. Nevertheless, companies want to be able to buy locally and farmers want to rely on a local collective and make their area and region benefit from the scheme. Finally, these respondents are concerned about the credibility of the system: for this, they prefer a control that doubles the photo-interpretation of a technician's visit, they are committed to setting up a reliable and serious certification system (international or national).

Table 4: *Preferences of the different categories of respondents according to scheme type*

Acteur	Farmers		Local Authorities		Companies		Total	
Classe	Eff.	% Obs.	Eff.	% Obs.	Eff.	% Obs.	**Eff.**	**% Obs.**
Local development system	15	34%	**16**	**80%**	8	36%	**39**	**45%**
OTC contracts	8	18%	4	20%	8	36%	**20**	**23%**
local supply within the international carbon market	10	23%	0	0%	5	23%	**15**	**17%**
National public policy scheme	**11**	**25%**	0	0%	1	5%	**12**	**14%**
Total	**44**	**100%**	**20**	**100%**	**22**	**100%**	**86**	
p-value = < 0,01 ; Khi2 = 21,70 ; ddl = 6,00								

The stakeholders' preferences for these different types of schemes are very much shared, particularly for companies and farmers (Table 4).

Discussion - conclusion

Our research aimed to test the opportunity to implement voluntary carbon markets to support the maintenance of hedgerows, in a context where a diversity of bocage support systems already exist (at national and local scales). It then aimed to clarify the form that these contracts could take.

A market involving a set of environmental services

The first significant result is that most of the respondents surveyed are interested in this type of measure. They prefer to enter a market that values mixed hedgerows. This result should be considered with caution as it concerns a statement of prospective intent and is based on a selected sample of respondents interested in our objective. Nevertheless, this result is confirmed by the analysis of the Choice experiment associated with this survey, which succeeds in identifying a potential price range for trading carbon credits from hedgerows; then by the results of the three focus groups according to the territories, in which the respondents have highlighted that they are ready to commit to the establishment of local carbon markets.

The interest in this new device is based on a diversity of motivations (technical, economic, environmental and social), which reflect the differences in the points of view of the stakeholders interviewed. However, for the majority of them, the scheme should promote hedgerows which produce a diversity of ecosystem services (ecological, landscape, water-related), even if this means limiting the efficiency of the service in terms of carbon storage. This reflects a desire to integrate this scheme into the continuity of prior commitments (local authority policies, agricultural practices). Stakeholders thus participate in a form of erasure of the climate objective in the face of the ambition of environmental coherence, which constitutes a way of managing environmental injunctions which is often seen as contractictory by the respondents (Thareau et al., 2014). Stakeholders, and in particular farmers, also participate in strengthening inertia in regard to local action, which is traditionally observed in public policy analyses (Bertrand, 2013). It should be noted that it is within companies that we encounter the highest number of respondents concerned about the climate efficiency of the scheme, even if it means transforming local landscapes and practices. Less rooted in agri-environmental schemes, companies can be drivers of transformation in local practices.

A variability of preferences related to contract

Our results distinguish four types of preferences regarding the objective of the contract. The contract which is preferred by all types of respondents, is flexible (in terms of duration of engagement and hedgerow length engaged), this result correspondswith research conducted on farmers' commitment to agri-environmental schemes (Ruto and Garrod, 2009; Espinosa-Goded et al., 2010; Christensen et al., 2011). We assumed that preferences for short and flexible contracts would be more asserted by farmers than by buyers or local authorities. However, we observed the opposite: farmers, more than other types of respondents prefer binding contracts. Companies and especially local authorities prefer more flexible contracts. The farmers' point of view is explained on the one hand by the fact that the majority of them have already developed important hedgerow lengths and the scheme would make it possible to finance pre-existing practices; on the other hand, they wish to ensure the credibility and robustness of the market via the terms of the contract while limiting the administrative complexity of the scheme (this ambition of administrative simplicity is in accordance with the literature). On the other hand, companies and local authorities see the scheme as leverage to engage new farmers in the implementation of hedgerows, by proposing conditions of engagement that allow them to test the market. This enables the facilitaion and enrolment of the highest possible number of farmers thus increasing the effectiveness of the scheme. From their point of view, the credibility of the market must be ensured by the attributes of the scheme.

A variabilty of preferences in relation to the scheme

Our research identifies four forms of schemes which are desirable from the respondents' perspective. Except for local authorities who largely prefer a "local development system" type, in which they would play a decisive role in the governance of the scheme, the other respondents have more fragmented preferences. They are partially linked to the respondent's experiences: farmers are more interested than others in schemes characterised by high intermediation that provides technical support and robust public certification of the effectiveness of the environmental service. These scheme attributes resemble the AEMs largely mobilized by these farmers. Companies prefer market driven or OTC contractual mecahnisms which are easily integrated into their business practices. The compatibility of the scheme with system, values and practices, in addition to respondent experience, helps to explain their preferences (Gherib, 2006; Spence et al, 2007)

What is at stake in repondents' preferences is the way in which trust between the parties and the credibility of the scheme are organised: via a direct and local link in local and over the counter development schemes, or via national or international institutions in the international and national market schemes. What is also at stake is the efficiency and cost of the scheme. Some respondents prefer to limit these costs and mainly pay for the ecosystem service itself, whereas others believe that the success of the device will rely on a consistent investment in governance tasks, which could be partly suypported by public investment via local authorities' budgets. Finally, the respondents' preferences also reflect visions of the system's anchoring in political strategies at different scales: at the level of companies only (willingly), in the context of territorial projects (local development) or finally in relation to national policies, created or not created in the context of the COP (national mechanism and international market). This anchoring contributes to the legibility and recognition expected, particularly from farmers.

Surprisingly, the objective to find new connections between farmers and enterprises in a local and communitarianism scheme seems more affirmed by companies than by farmers. With regard to companies; firstly, it is motivated by the ambition to control the implementation of storage measures; secondly to be able to report, in particular to their employees, on the company's territory-specific commitment; and finally, by the desire to strengthen commercial relationships with their suppliers (Tronquet et al., 2017).

Inertia and renewal of transitional measures towards agro-ecology

Our research aims to suggest the development of an innovative scheme for the valorization of ecosystem services. However, it also highlights a certain inertia in the preferences of farmers and of local authorities (with regard to the objective and mechanisims of the scheme). In this proposed scheme, companies are new players. With them, two major challenges are affirmed: the desire to anchor the system in the territories via direct links between buyers and sellers and the ambition of measurable climate efficiency. These ambitions are factors for renewal and social innovation in a context of a profusion of agri-environmental measures to maintain hedgerows. These local carbon markets could make it possible to create mixed workspaces in the evolution of agricultural models and practices, which mobilize new stakeholders (companies), and which seem to be able to contribute to improving knowledge and recognition of the role of farmers in their territories.

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MAKING THE AGROECOLOGICAL TURN: IDENTIFICATION OF FARM-LEVEL SOCIOTECHNICAL ADOPTION FACTORS AND DETERMINANTS

Anda Adamsone-Fiskovica, Mikelis Grivins

Baltic Studies Centre, Latvia

Abstract: The European Green Deal, which strives to move towards environment- and climate-friendly farming, stipulates a number of agroecological measures to reach this ambition. Some of the proposed technologies include intercropping, catch-crops, and green manure application on farms, which are practically feasible for the introduction of sustainable soil management in horticulture. However, until now their uptake has been quite limited despite the demonstrated effectiveness.

The current research aims to systematically review the current state of the art of research and knowledge with regard to the factors that influence the adoption or non-adoption of the selected technologies by farmers. The search of peer-reviewed articles published in 2010-2020 was carried out in the Scopus and Web of Science databases. Based on a set of keywords, a total of 122 unique articles were retrieved for initial scanning for relevance, with the list subsequently narrowed down to 63 articles retained for full-text reading.

There has been a gradual increase in the number of articles addressing the adoption of the selected technologies over the decade. In terms of the geographic scope there is a considerable lack of studies from Europe, with the majority covering Africa and Asia, as well as the USA. The selected technologies are mostly addressed with reference to conservation agriculture, best management practices, climate-smart agriculture, sustainable intensification, and organic agriculture. While there is a general lack of theory-guided studies, the most frequently used ones are the Theory of planned behaviour and the Diffusion of innovations theory. Empirical data collection methods cover a mix of qualitative and quantitative methods, yet these are dominated by semi-structured or structured surveys focusing on the correlations between the adoption and a set of variables.

Some of the initial observations show that factors studied by researchers include a diverse range of internal and external ones spanning across agronomic, economic, technological, environmental, political, social and psychological domains. While mostly the focus is on farm characteristics such as farm size, land tenure, livestock ownership, irrigation system, soil quality, fertilizer use, as well as labour force, income sources, loans/debts, along with farmer traits such as age, gender, education, farming experience, employment status, there are studies also highlighting the role of farmer’s objectives, motives, orientations, risk attitude, aesthetic values, cultural preferences, and social participation. Other explored factors include information sources, availability inputs and credit, distance to market, access to extension services, presence of policy incentives, not to mention place-specific climate and weather conditions.

THEME 4 – FOOD SYSTEMS, NETWORKS AND POWER STRUCTURES

Agri-food systems are among the most important human-environmental systems that shape our society. The sustainability of food systems is essential for food security and nutrition. Today, many of the current food systems have lost their connection with nature and/or with society and their sustainability is threatened by diverse challenges such as climate change, price volatility, food safety and consumer mistrust. To tackle these challenges, systemic changes in structure (e.g. networks and power structures), practices (e.g. rules and habits) and culture (e.g. norms and values) are required.

Creating spaces for collective action seems to be an effective strategy in reducing uncertainties and increasing transformative capacity. This requires collective action, which current governance structures and power are often restraining. Although agri-food networks are emerging and can be successful at a small scale, these networks often fall short of reaching their goal to bring about change at agri-food system level. Among the possible barriers is the fact that both practice and research remain focused on how innovations and sustainability practices are shaped at individual firm level, while agri-food systems and networks – as dynamic complex systems – are strongly interconnected. Furthermore, the urban-rural fringe is a still existing dichotomy in food systems studies. We need to find systemic approaches to look beyond these dichotomies and to realise new and re-connections. This is required not only in research but also in policy and practice. The challenge is also to learn how conventional food systems can (re)connect with nature and society in order to increase their transformative capacity.

CIVIC FOOD NETWORKS AND SUSTAINABILITY TRANSITIONS: THE EXAMPLE OF ORGANIC REGIONS AND ANTI-PESTICIDE MOVEMENTS IN THE BELLUNO PROVINCE, ITALY

Simona Zollet[a]

[a] Hiroshima University, Graduate School for International Development and Cooperation, TAOYAKA Program

Abstract

In a context where the unsustainability of mainstream agri-food systems is increasingly evident, initiatives to promote sustainable agriculture and food systems localization have been multiplying. However, sustainability transitions require systemic changes in terms of practices, culture and structures (such as networks and governance systems). There is growing evidence of the role that civil society plays in creating or supporting sustainability-oriented innovations in agri-food systems, but in the context of territorial agri-food system governance, civil society organizations haven not been receiving much attention. The paper focuses on the Belluno Province, in the north-eastern Italian Alps. This area is similar to other marginal mountainous areas in Europe, where dynamics of agricultural abandonment are being addressed by increasing agricultural multifunctionality and a turn towards organic and other forms of environmentally friendly farming. At the same time, however, new dynamics of agricultural intensification are also emerging, driven by outside interests and potentially damaging for the local population and environment. The research explores two strategies created in response to this phenomenon and aimed at promoting territorial-level changes in agri-food system sustainability: the first is the creation of an organic district, and the second is a social movement mobilizing to decrease agricultural pesticide use. The research draws upon interviews conducted with organic farmers, local administrators, agricultural experts and consumer organizations to explore how civil society action was one of the key factors in the success or failure of each of these strategies.

Introduction

Agri-food systems are among the most important social-ecological systems shaping our world. Contemporary industrial-based models of food production, distribution and consumption, however, are coming under increasing scrutiny for their multiple dimensions of unsustainability. In addition, challenges such as climate change, environmental degradation and growing consumer mistrust have been intensifying (McDonagh, 2013). Despite the considerable attention that the concept of sustainability has been receiving in the past two decades, the development trajectory of agri-food systems remains on a largely unsustainable track (Abson et al., 2016). Sustainability transitions require systemic changes in terms of practices, culture and structures (such as networks and governance systems). In the case of practices and cultural change, and also in the case of networks, there is much evidence of the role that civil society plays in creating or supporting sustainability-oriented innovations – particularly social innovations – in agri-food systems (Kirwan, Ilbery, Maye, & Carey, 2013). When it comes to agri-food system governance, however, research has focused mainly on the role of policy and market actors in steering sustainability transitions, with civil society and social movements receiving considerably less attention (Andree, Clark, Levkoe, & Lowitt, 2019). Moreover, while the role of civil society in influencing the 'food' end of agri-food networks (see the literature on alternative/local food networks) is well-established, the role of civil society and social movements in steering changes in farming practices has received less attention.

This study focuses on civil society organizations' (CSOs) and social movements' efforts aimed at decreasing pesticide use in agriculture, especially those playing out at the municipality and territorial level. Such efforts have been multiplying across Europe (PAN, n.d.). The conceptual framework used in this paper seeks to bring together the concept of civic food networks (CFNs) (Renting, Schermer, & Rossi,

2012) arising from the Alternative Agri-food Networks (AAFN) literature, and the literature on the role of civil society and social movements in sustainability transitions. Despite having developed as separate disciplinary fields, AAFN and sustainability transition research have many common aspects: from a sustainability transition perspective, AAFNs have been described as niche innovations with the potential to foster socio-ecological transformations within the dominant food regime (see e.g. Lutz & Schachinger (2013)). Moreover, in both literatures there has been increasing attention for the role of civil society and social movements in developing initiatives that can facilitate sustainability transitions in agri-food systems (Köhler et al., 2019; Renting et al., 2012; Seyfang & Smith, 2007).

In addition to the above, changes in agri-food system governance are being influenced by the shift towards decentralized forms of government and by the growing demands placed upon peripheric areas to manage their own development (Darnhofer, 2015). This implies a need for increased civic participation and direct democracy processes. In this sense, multi-actor governance approaches are increasingly recognized as important strategies to promote sustainability transitions at a territorial level (Koopmans, Rogge, Mettepenningen, Knickel, & Šūmane, 2018).

Based on these considerations, the paper sets out to answer the following research questions: 1) how do social movements/CSOs influence the creation of policies oriented towards agri-food system sustainability (specifically related to pesticide reduction in agriculture? Particularly, in what circumstances do they establish themselves as significant players in agri-food system governance transition processes? And 3), does this have wider implications for sustainability transitions?

The article is structured as follows. Section 2 introduces the conceptual framework, which draws upon sustainability transitions, civic food networks and multi-actor governance literature. Section 3 describes the research methods and the study area. Section 4 first gives a narrative chronological description of the development of the case study and then presents the research findings. Section 5 discusses the findings in relation to the theoretical lenses and suggests implications for further research.

2. Conceptual framework

2.1 The local dimension and multi-actor governance

Research on the role of governance in sustainability transition has been shifting from national- to subnational-level processes and policies. But while the city level is received much attention, configurations that are either smaller (e.g. smaller municipalities), or that are defined according to other types of geographical (non-administrative) boundaries are less represented. Large scale urban areas also tend to be more represented compared to more rural settings. In this sense, cross-fertilization with AAFN literature, which has been historically more rooted in the 'local' – and to a large extent 'rural' – context can address this shortcoming. At the same time, the focus in sustainability transition literature on meso-level change (Geels, 2004), can help AAFN literature to shift away from the very 'localized' kind of analysis that has been the source of much criticism (DuPuis & Goodman, 2005; Köhler et al., 2019; Winter, 2003).

Moreover, the increasing withdrawal of the national state calls for non-government actors to take upon themselves new roles and responsibilities in defining local agri-food and rural policies (Renting et al., 2012). In this sense, multi-actor governance approaches are increasingly recognized as important strategies to ensure the co-creation of knowledge between all involved stakeholders and promote collaboration, potentially supporting the expansion of technical and/or social innovations at multiple scales (Koopmans et al., 2018; Pigford, Hickey, & Klerkx, 2018). The increased focus on sub-national governance levels in sustainability transition research may be partly due to the fact that at these levels the "devolution (or abdication) of state responsibility under neoliberalism opens space to do things differently" (Andree et al., 2019, p. xii). One compelling reason to focus on grassroots action (in agri-food systems and beyond) emerging from local CSOs is that it can potentially be more effective than top-down policies in delivering sustainability benefits. CSOs can draw upon contextualised knowledge about what is important to local people, including how to present sustainability issues in ways that are more relevant and meaningful to them. This in turn can lead to solutions that fit the local context better (Seyfang & Smith, 2007). 'Grassroots innovations' have been described as "networks of activists and organisations generating novel bottom–up solutions for sustainable development; solutions that respond to the local situation and the interests and values of the communities involved" (Seyfang & Smith, 2007, p. 585).

2.2 The role of CSOs in agri-food sustainability transitions

Sustainability transitions are multi-dimensional and multi-actor processes, encompassing a range of elements and actions performed by a variety of actors and involving different kinds of agency and co-evolution. They are also characterized by a "dialectic relationship between stability and change" (Köhler et al., 2019, p. 2), where impulses for radical change are counterbalanced by attempts to maintain the status quo promoted by entrenched systems of power, 'lock-ins' and path dependence mechanisms. Finally, they entail a normative directionality, because sustainability has the characteristics of a public good and therefore private actors and the market often have no incentive to address it. These aspects point to the role that public policy (rather than the market) play, as well as the need for a dialogue among different actors, including CSOs. The role of the latter in steering the transformation of systems of production and consumption (including the agri-food system) is being increasingly recognized (Köhler et al., 2019). CSOs and social movements can influence sustainability transitions according to three major pathways: 1) by building public support for transition policies; 2) by creating protected spaces for the development of grassroots innovations (Seyfang & Smith, 2007); and 3) by promoting broader cultural shifts and redefinitions of values and beliefs that can drive changes in the preferences and everyday practices of both consumers and producers (Köhler et al., 2019).

2.3 Civic Food Networks

While early research on AAFNs mainly focused mainly on their potential to contribute to farm multifunctionality and rural development, more recent works have also explored the role of AAFNs in bringing about deeper and wider transformations in the organization of agri-food systems (Kirwan et al., 2013; Lamine, Renting, Rossi, Wiskerke, & Brunori, 2012). In parallel, the importance placed on citizens playing an active role in agri-food system governance (beyond being mere consumers) has also being growing, as demonstrated by concepts such as 'food citizenship', 'food democracy' and 'civic agriculture' (Lyson, 2005). This paper adopts the 'civic food network' (CFN) concept proposed by Renting et al. (2012) in an attempt to specifically address the role of civil society and to engage with the idea of citizens (producers and consumers alike) attempting to bring food democracy into agri-food systems. "The concept of food democracy is especially relevant as it "ideally means that all members of an agro-food system have equal and effective opportunities for participation in shaping that system, as well as knowledge about the relevant alternative ways of designing and operating the system" (Hassanein, 2003, p. 83).

CFNs influence agri-food system change in two ways: 1) by being a source of grassroots innovation and 2) as emerging governance mechanism (Renting et al., 2012). This is similar to the role of CSOs in sustainability transitions described in the previous section. In reclaiming influence over the way food is produced, distributed and consumed, civil society-based initiatives create spaces for innovation through processes of social learning and capacity-building. In turn, these innovations may pave the way for novel arrangements in agri-food governance mechanisms and create new negotiation spaces to interact either with market actors or with public administrations (Renting et al., 2012). While AAFNs literature has often focused on aspects concerning changing relations in market exchanges and food provisioning, the nexus between CSOs and public institutions has received less attention. Moreover, the cases that have been explored along the civil society-(local) government axis mainly fall into the category of local food policy councils and public procurement schemes. Cases such as these illustrate how CSOs can work together with local administrations to improve agri-food system sustainability (Renting et al., 2012). However, they focus primarily on the 'food' end of the agri-food system, while there are fewer documented cases of the role of civic food networks in steering policies aimed at changing local agricultural practices. Two emerging examples are the movements towards the creation of organic districts (Stotten, Bui, Pugliese, & Lamine, 2017) and social mobilizations fighting for stricter regulations of pesticide use within municipalities or in (sub-)regional contexts.

Organic Districts

Organic districts (also called 'organic regions' or eco-regions), have been defined as territories 'naturally devoted to organic, where farmers, citizens, public authorities, realize an agreement aimed at the sustainable management of local resources, based on the principles of organic farming and agroecology' (IN.N.E.R, 2017). So far, organic districts have been established mainly in Italy (where 32 exist so far) and to a lesser extent in other European and non-European countries. Although most organic districts across Italy and Europe are still in their infancy and research on their development is still scarce, interest in these experiences has been growing, particularly in relation to their holistic and meso-scale (territorial) approach, which promises to be a way to scale-up agri-food system sustainability in a way that other forms of AAFNs are not able to do. The creation of organic districts has been described as a process driven by cooperation among various territorial actors and based on participatory approaches open to all civil society representatives. A review of the existing literature on the development organic districts, however reveals a common array of challenges and bottlenecks in this sense (Lamine, 2015; Stotten et al., 2017). A major issue is that in practice the wider local community is often only marginally involved in the organic district creation process, which remains primarily projects driven by producers' organizations, market actors, or local institutions. This translates into a lack of citizen understanding of the potential of organic districts and into a lack of interest in actively supporting them.

Municipal bylaws on pesticide use

Cases of municipal-level laws regulating pesticide use have been documented in academic literature for Canada (Pralle, 2006) and to a lesser extent for Europe (Kristoffersen et al., 2008). There is evidence that in Europe this is an issue of increasing concern. Europe's Pesticide Action Network (PAN)'s campaign 'Pesticide Free Towns', which tracks the progress of municipalities across Europe in banning pesticide use in public areas (PAN, n.d.) In most of these cases, however, the laws refer to non-agricultural pesticide use, such as the use of herbicide to manage weeds in urban public areas or in residential settings. Less researched is the topic of local-level mobilization against agricultural pesticide use at municipal level. The most notorious example is the municipality of Mals in the South Tyrol region of Italy, the site of an ongoing grassroots mobilization against large-scale, agrochemical-intensive agriculture (Ackerman-Leist, 2017). In Mals, a diverse group of citizens came together to establish the *Promotorenkomitees für eine pestizidfreie Gemeinde Mals* (Advocacy Committee for a Pesticide-Free Mals), demanding stricter municipal laws to protect citizens' health, promote sustainable agriculture and completely ban agrichemical use within municipal boundaries. Their campaign won an uprising of public support, including from the mayor. While this is the most famous case, also due to its success, similar cases have been occurring in other parts of Italy, including in the Belluno province (located not far from Mals) which is the subject of this paper.

3. Methodology

3.1 Study area: Belluno Province

The Belluno province (3672 km^2) is located in the northern part of the Veneto region, Italy. Despite being the largest province in the region, it is almost entirely mountainous, and sparsely populated. Most of the 61 municipalities of the province have less than 5000 inhabitants, and the population is concentrated in the southern part of the province (Valbelluna), where the two largest municipalities (Belluno and Feltre) are located. The province hosts the Dolomiti Bellunesi National Park and the largest portion of the Dolomiti Unesco World Heritage site, and as such is recognized as an area of high natural and scenic value. The agricultural sector is mainly organized around the dairy supply chain, with dairy farms representing 52,9 per cent of the total as of 2010. Most of the agricultural land is used for fodder production (hay and maize), and as such does not require intensive pesticide use (De Pin, 2014). Similar to other mountainous areas in Europe, agricultural abandonment is a widespread phenomenon, as demonstrated by a 63 per cent decrease of the number of farms over the 2000-2010 period (Giupponi, Ramanzin, Sturaro, & Fuser, 2006). In addition, the dairy sector has been suffering as a result of milk liberalization policies.

Against this backdrop of agricultural decline in the conventional sector, two new trends have been emerging: first, the increase of multifunctional and diversified agricultural activities that combine agriculture, local food production and tourism. Environmentally friendly farming, localized food supply chains and tourism-oriented activities are increasingly being recognized as a way to support the local economy, in recognition of the fact that intensive models of agriculture are not suitable for the area and would not be competitive due to geographical constraints (Camera di Commercio Treviso e Belluno Dolomiti, 2017).

The second trend playing out in the province, particularly in the southern part, is the establishment and expansion of large scale intensive agricultural operations, especially vineyards. This kind of development has been driven mainly by entrepreneurs from the nearby provinces (such as Treviso and Trento), attracted by the lower land prices in the Belluno province. The areas where new vineyards have been implanted are expanding at a fast pace, partly driven by the so-called 'Prosecco rush'. Prosecco, a kind of sparkling wine, has gained enormous popularity globally, leading to the massive expansion of viticulture within the zones designated as traditional Prosecco production areas, where there is now virtually no more land available for new vineyards. While the original production area was limited to a few municipalities in the neighbouring Treviso Province, in 2009 it was expanded to include almost all the Veneto region, including the southern part of the Belluno province. This caused an upsurge of concern from local people, worried by the health and environmental problems linked to pesticide use in conventional viticulture and by the threat of the destruction of local biodiversity and landscape (Basso, 2018). Since 2008, various municipal-level resident groups have been organizing independently to protest this kind of agricultural development. The expanding scale of the phenomenon, however, prompted the creation of the provincial-level CSO 'Terra Bellunese' in 2014, which one year later launched the campaign 'Liberi dai Veleni' (Free from poisons). The campaign was supported by a large number of CSOs in the Belluno province, ranging from Solidarity Purchasing Groups (*Gruppi d'Acquisto Solidale*, GAS), environmental organizations, and the local organic farmers association (Dolomitibio).

This case study is noteworthy for several reasons: the first is the co-occurrence of the two rural and agricultural development dynamics described above, which point to two different visions of agri-food system sustainability and to two different rural futures. Second, it relates to contemporary debates about the sustainability of marginal rural areas and to new processes such as land consolidation and land grabbing by outside interests. Third, the area is both the site of a large-scale social mobilization against pesticides and of a proposed provincial-level organic district project, which are a direct response of the above dynamics. Finally, the case does not involve a single municipality, as in Mals, but a larger geographical area that encompasses several municipalities, and therefore can be seen as a large-scale effort towards agri-food system change.

3.2 Research methods

Data for this research was gathered from semi-structured interviews, focus groups and document analysis. While the study was conceived as a research project on newcomer organic farmers, and therefore it originally focused on individual and farm-level dynamics, it soon became clear that wider territorial-level dynamics were influencing the choices and actions not only of organic farmers, but more generally of the more environmentally-conscious local administrations and civil society organizations. As a result, additional interviews with non-farmer actors were undertaken in order to gain a broader understanding of these dynamics and the interplay among different actors.

A total of 33 interviews were conducted in July 2018 and August 2019, plus one focus group in August 2019. Among the interviews, 26 involved organic farmers, selected purposively to a) include a variety of farm types and b) to include individuals involved in the *Liberi dai Veleni* campaign and in the organic district project.

Two interviews were conducted with local administrators (representing the Feltre municipality and the Provincial government respectively) and two with agricultural experts. These institutional respondents were specifically selected because they took part in the organic district project and, in the case of the Feltre municipality representative, because of their outright support for the *Liberi dai Veleni* campaign. Finally, three interviews were conducted with spokespeople from local consumer groups – one fair-trade cooperative and two of the six GAS of the Belluno province. The focus group was conducted with 15 members of a third local GAS.

Interview questions addressed the topic of networks and participation in CSOs and projects addressing local agri-food system issues, and views on the future direction (imagined and desired) of the province in terms of rural development and agri-food system configurations. The interviews, ranging in length between one to three hours, were conducted in Italian and subsequently transcribed and translated into English. Interview data and field notes were then analyzed using thematic analysis (Braun and Clarke, 2006): the content was first coded, and then the codes were organized and grouped to identify patterns (themes) within the dataset. Secondary data, particularly press articles from local newspapers, were also used to reconstruct the timeline of events related to the organic district project and the anti-pesticide movement.

4. Results and Discussion

The 'battle against the vineyards': the birth of the organic district project and of the *Liberi dai Veleni* campaign

In 2014, the Dolomiti Bellunesi National Park (which had previously developed some initiatives to support organic farming within its territory) launched the idea of creating an organic district in the whole Province (Parco Nazionale Dolomiti Bellunesi, 2014). Even at this early stage two aspects were clear: the first was the emphasis on the Province's high natural value, which made it 'naturally' suitable for the creation of an organic district; and the second was the organic district could be used to contrast the dynamics of agricultural intensification that were starting to occur in those same years. At the time, however, the proposal – aimed at local farmers, agricultural associations and other relevant stakeholders – failed to attract any substantial interest and was eventually shelved.

The idea was revived in 2017 through an EU-funded project that involved public and private partners: the local agricultural high school, the municipality of Feltre, the University of Padua, AveProBi (the regional organic farmer association), the Dolomiti Bellunesi National Park and one large-scale organic farm). The stated aims of the project were to gauge interest in the creation of the organic district and to construct a network to support the spread of organic farming in the Belluno province. Despite the area's 'vocation' for organic production, organically farmed areas are limited, lower than the regional and national averages. The project therefore aimed at building linkages between research, industry and farmers and to understand the kind of technical support needed to encourage the conversion to organic. Over the course of the project, nine open focus groups where held, each with a different focus, mainly technical (growing organic cereal crops, aromatic herbs, soil fertility). Some focus groups also discussed public procurements and group certification (SITIABB, 2018). After the end of the two-year project, however, no further announcements were made about the creation of the organic district or about future developments of the idea.

In 2014, roughly at the same time as the first organic district proposal, citizens' growing opposition to the 'pesticide threat' coalesced around the civil society movement '*Terra Bellunese'.* Aware that the only way to impose stricter rules on pesticide use in a timely manner was to intervene on municipal regulations, the movement decided to focus on changing the municipal *Regolamento di Polizia Rurale* (Rural Police Regulations, RPR) (Poli, 2018). RPRs are municipal bylaws that regulate agricultural and land use practices within the municipal territory, including agrochemical use. As the existing RPRs in most municipalities were obsolete and inadequate to protect citizens' health and the environment in the face of new agricultural dynamics, *Terra Bellunese* drafted a new version. This RPR proposal was the concerted effort of the movement organizers, all local people from diverse professional backgrounds (teachers, organic farmers, lawyers and architects among others). Operating strictly on a volunteer basis, they researched the issue and drafted a proposal for more stringent regulations on the use of agrochemicals (stricter than the current national level regulation). Rather than prohibiting specific chemical substances or products, the new proposal bans specific hazard statements, thus making it automatically applicable to any new product released on the market. This initial draft was sent to all municipalities of the province for discussion. Furthermore, as part of the *Liberi dai Veleni* campaign *Terra Bellunese* organized several events, among which a signature collection, information sessions with doctors and scientists to inform the public about pesticide-related issues, and several public protests and marches. The goal of these activities was to show the opposition of the local population, influence public opinion and encourage municipalities to take a clear stand on the matter by adopting the new RPR.

Opposing the vineyard threat: 'land grabbing' and the emerging of a common identity oriented towards organic farming

The concern caused by the expansion of intensive cultivations clearly emerged from the interviews with farmers and institutional stakeholders alike. This concern takes two forms: apprehension for the increase in pesticide use, and frustration towards the idea of 'outsiders' buying up land. These two processes are both perceived in a strongly negative way and amplify each other. Significant in this respect are the words used by respondents to describe this process: 'invasion', 'colonization' and even 'land-grabbing'.

"There are some local entrepreneurs, but the majority is from Treviso, and they are really buying up – without most people knowing – hectares upon hectares of land. And after they buy, they can do whatever they want."

"We need to educate local people not to sell their land, otherwise it will be a disaster like in those places in the Treviso area. […] The problem really exists, and in some places here it is turning into an emergency. In [place name] they are spraying [pesticides] twice a week"

"There are continuous attempts on the part of entrepreneurs from Treviso of snatching up land, and we will become a place to be conquered ("terra di conquista"). Because their land is very expensive while here people are willing to give it away it for cheap, and we'll have Prosecco everywhere"

This sense of urgency is shared by consumer groups as well. In the GAS focus group and interviews, vineyards were indicated as the most urgent local issue on the topic of agriculture and environmental sustainability. Non-farmer respondents frequently highlighted the need to supporting organic farming to contribute to safeguarding the territory from these dynamics. There was also a consensus around the growing awareness level among the general population, attributed to the *Liberi dai Veleni* campaign.

At the same time, the idea of creating an organic district emerged over and over from different stakeholder interviews. The Belluno province was consistently portrayed as being uniquely biodiversity-rich, characterized by a high natural value and relatively wild and pristine landscapes. The comparisons with the two neighbouring provinces of Trento and Treviso, where monocultures have simplified the landscape and polluted soil and water (and where the 'land grabbers' come from), further contribute to the perception that the Belluno province is 'different' and 'naturally suitable for organic farming'.

"The Valbelluna is one of the most biodiversity-rich areas in Italy […] and where there is already a high level of natural biodiversity, organic farming finds its 'natural habitat'. It's much easier to do organic here."

While many of the established organic districts in Italy have a sub-provincial territorial extension, in this case the organic district is always imagined and discussed as encompassing the whole provincial area. This strengthens the sense of distinctiveness compared to the neighbouring provinces, an image that is tied to its higher naturality and lack of intensive farming. In one of the respondents' words: "*The organic district would be a good way to make the Belluno Province shine like a jewel, to stand out further from the neighbouring provinces of Trento and Treviso*" (20).

The establishment of organic regions in marginal areas is sometimes facilitated by specific territorial characteristics that can make the establishment and clustering of organic farms easier (Lamine, 2015). In some cases, organic districts were developed using the discourse of "a region left out by modernity" (Stotten et al., 2017, p. 147). This kind of narrative emerged often from the respondents' words, and was used to symbolically reclaim the dignity of the province. Despite having historically lagged behind compared to its richer neighbours, a newfound awareness is emerging of how this 'underdevelopment' might be beneficial in the perspective of a 'different' model of territorial development.

"In our misfortune we have been lucky: our poverty meant that we didn't engage in the large-scale destruction of our land, which is still relatively uncontaminated. So we should avoid poisoning it now, and later having to clean it up how they're doing in Trentino. Let's make organic the obvious choice for the Province."

"Until recently we envied the neighbouring provinces their economic dynamism. But if we go and look at those provinces, much richer than us from a purely economic standpoint, we'll see that they are based on unsustainable models of development."

It is possible that the recent dynamics of land acquisition and intensification may have strengthened this narrative, leading to the creation of a stronger identity in this sense.

The failure of the organic district project implementation

If the vineyard issue is perceived as such an urgent matter and the organic district is constructed as the obvious solution, why was its creation unsuccessful? The analysis of the respondents' interviews reveals four major issues: a) the limited agency of local organic producers; b) the unwillingness of farmers' unions to support the project; c) the lack of involvement of many of the local administrations; d) the lack of provincial-level coordination; and e) the lack of public participation.

The first issue was the inability on the part of local organic farms to play a significant role in moving the process along. Despite the involvement of the regional organic farmers' association (AveProBi), the project did not originally include the provincial organic farm association (DolomitiBio) in the project. In the words of one of its members, *"a group promoting an organic district that doesn't have the representatives of local organic producers as one of its main promoters is an anomaly. It sounds very top-down".*

This is the consequence of several weaknesses within the association: the member farms are for the most part small scale family farms, with very few resources (human and financial) to invest in the project. Furthermore, the association almost exclusively includes organic farms in the southern part of the Province, revealing a territorial disconnection with the farmers in the northern part. Finally, farms without the organic certification cannot join, which results in the further under-representation of the number of organic farms in the province. This inability of presenting a united front is an element of intrinsic fragility that played a major part in holding back the establishment of the organic district.

This fragility is recognized by organic producers and by non-farming respondents alike and can be further connected with the second issue: the unwillingness of farmers' unions to support the project. Agriculture in the province is strongly specialized around intensive dairy farming and lacks diversification, and farmers' unions are unwilling to actively endorse organic farming. The attitude of the various farmers' organizations and unions – which represent mainly conventional farmers – was defined as 'overly cautious' at best and as 'openly against' at worst. From their standpoint the organic district should be limited to one of the northern districts, where a small cluster of organic dairy farms is already established. Even though a provincial-wide district is regarded as important to steer the future development of the area in a sustainable direction, sectorial interests work against its establishment. One of the institutional representatives described the attitude of farmers' unions as such:

"The farmers' unions do not care about it [the organic district] because most of their social base is afraid that talking about 'organic' means, indirectly, to talk in a negative way about conventional. They should understand that having organic farms nearby can benefit them too. But if we wait for them, nothing will ever happen."

The inability or unwillingness to act that characterizes the various counterparts within the agricultural sector and the lack of dialogue between organic and conventional is mirrored by the inertia of most local administrations. Farmer respondents noted a general unwillingness to concretely support initiatives aimed at increasing agricultural sustainability at the municipal level:

I think they should express more clearly their support for organic practices, something that they don't do for political reasons. […] very few are willing to do this, and […] to go against the status quo.

The issue that is perhaps the most critical from a public administration standpoint is the lack of a strong provincial-level leadership which could steward the creation of the organic district and bring local administrations together. This is a consequence of the application of the 56/2014 Law (Delrio) which, in an attempt to give more power to municipal administrations, essentially stripped provincial governments of decisional powers and financial resources. However, while this may be beneficial for larger metropolitan areas, in a sparsely populated territory with no large cities to take on a coordinator role the lack of a Provincial government proved to be one of the biggest reasons why the organic district project did not progress to the implementation phase.

Finally, there was very little involvement of civil society groups in the definition of the organic district project, which was essentially the result of 'closed door' decisions taken by the project partners. And while the general public was invited to the public meetings, the project failed to inspire widespread support among the civil society. In this case the co-production aspect, where stakeholders define a common narrative and work towards identifying common problems and goals, was overlooked. While this common narrative was clear to the promoters of the project, it failed to involve the local population and threfore to gain public recognition and support.

The Rural Police Regulation approval: a model for a 'bottom up' organic district?

Comparing the organic district project to the way the RPR were created (and ultimately approved) can shed some light on how a more successful transition may occur, as the RPR can be considered as a more successful example of co-production and cooperation. The most interesting case is that of the municipality of Feltre. When the RPR proposal by Terra Bellunese was sent to all municipal administrations of the province for discussion, Feltre did something unusual: let its citizens discuss the matter and decide whether they wanted to approve it. This was constructed as a direct democracy experiment held as a part of the 'citizenship labs' promoted by the municipality. During the meetings, open to everyone who wished to participate, the proposal was collectively discussed and modified. The process started in October 2015 and ended in October 2016 with the approval of *Terra Bellunese*'s proposal. One of the *Terra Bellunese* founders described it as:

[…] the result of one year and half of work. It started from the bottom up, and it was surprising because in the end several [other] municipalities adopted it. Feltre was incredible, we held 11 meetings and at the beginning we encountered the opposition of conventional farmers and of farmers' associations, because they felt it was too limiting, but in the end it was approved.

The most notable aspect of the RPR is that it was fashioned through a process of co-creation involving a close cooperation between civil society and the municipal government. It also highlights citizens' willingness to become involved first-hand in decision making process regarding their territory and its future development, especially when faced with urgent threats to public health and the local environment. Eventually the RPR was approved without significant changes by Belluno and by other 12 municipalities of the province (without undergoing the same participatory process as Feltre). Although the new RPR does not automatically ensure farmers' compliance (although municipal personnel are being trained to carry out inspections), it is playing a significant role in mitigating the spread of new intensively managed vineyards. In one of the new vineyards created in the territory of the Feltre municipality, for example, the original plan to plant Prosecco grapes was abandoned, and the owners switched to resistant grape varieties which require less treatments.

The RPR experience therefore demonstrated what a committed citizenship could achieve when paired with a supportive administration, and the ripple effects created in the surrounding municipalities. Respondents often spontaneously compared the RPR creation to the organic district project, emphasizing the bottom-up aspects of the former to the distinct top-down flavour of the latter. The creation of an organic district 'from the bottom-up' was often mentioned as one possible path to revive the organic district project. The following quote shows the organic district being conceptualized as a collective, civil society- and citizen-led approach:

" there are some new efforts being made by the various GAS in the province, which are starting to network among themselves and talk about [the organic district]... if we could spread this organic district idea at a more popular level, if it were something in which citizens believe in as well, then it would become much easier. […]

Further steps forward came again from Feltre. The local administration decided to support organic farming directly by renting municipally-owned lend to organic farmers, and also promoted citizenship labs on issues such as green mobility, renewable energy use and waste management. These meetings are a further attempt to create spaces where perspectives of a more sustainable future can be imagined, shared and discussed. From this point of view, and through the involvement of a wider group of citizens, the organic district can become more than a territorial economic development strategy promoted by farmer groups (as it is often the case): it can be re-imagined as a comprehensive framework that encompasses environment and biodiversity protection, public health, local food systems, transportation, energy use. This goes in the direction indicated by similar experiences, most notably the Drome Valley in France (Lamine, 2015). Striving to create this kind of organic district, one that goes beyond territorial branding and promotion, might eventually give a deeper significance to the concept of organic district itself:

"*Creating an organic district is very easy… since there is no reference law yet, me and you could even create one right now. [..] There are 29 of them in Italy, but nobody knows about most of them. It's nothing but a self-proclamation. […] they are not active, and we would like ours to truly support change among farmers, but also to stimulate a transformation in the direction of sustainable energy, ecotourism, transportation… it's a bit of a visionary project, really.*"

While the focus of organic districts is usually on agriculture and food production, this case study offers an example of a strategy to involve citizens more directly in processes of sustainability transitions at the local and territorial level, and how the concept of organic district may be redefined to include broader sustainability concerns. It is not only the system of production and marketing/distribution that needs to change, but the behaviour of citizen-consumers as well (Lamine, 2015). In the words of one respondent:

"it's easy to tell [farmers] what to do. The kind of attitude like "It's okay to do organic, but you, farmer, should do it… I, consumer, will keep using my car, shopping at the supermarket" …an organic district should be a place where farmers grow organically, and citizens also behave accordingly. And therefore, [a place] where they think about sustainable transportation, localizing consumption and all those other aspects."

Moreover, while the creation of the organic district has so far failed because it aimed at reaching an a-priori consensus among a narrowly-selected group of stakeholders, the way forward might be found in a model closer to that of the RPR and of citizenship labs. This might involve drafting a proposal with the participation of all civil society actors willing to be involved, and then trying to reach a consensus through an open process of co-creation. When thinking about the possible scenarios of change and transition towards sustainability in the Belluno province, a future where the constellation of existing stakeholders and group of stakeholders come together to create a network of small, concrete initiatives from the bottom up starts to emerge. For example,

"places where organic farmers can bring their products, but not just a sales point, something more innovative… open to new ideas about food, environment, maybe even tourism […] places that keep nurturing the chances for farmers to cooperate among themselves, and to expand these interactions to the wider society."

One final issue is the fact that the decision to promote direct democracy processes depends on local administrations. For example, the municipality most affected by the expansion of vineyards did not accept the new regulations, despite widespread protests from its citizens. While this could have been an opportunity to display a common stance on the topic of territorial sustainability, it was not embraced by all local administrations. This points once again towards a lack of territorial cohesion, where specific interests prevail over the common good. This is perceived as a pervasive issue, starting from organic farmers (who have not been able to come together in a formal group) to civil society associations (often divided by ideological differences despite having similar visions about territorial sustainability) to local administrations. As summarized by one of participants,

"*One of the greatest limitations […] is the lack of a common vision, the idea of moving ahead together. A sort of 'common good' (*bene comune*) idea, of doing things together because eventually everyone will benefit from them."*

Conclusions

It has been recognized that systemic change in agri-food systems unfolding at territorial level requires not only the cooperation between public and private sector organizations, but also inclusive participation and bottom up involvement of civil society groups (Favilli, Hycent, & Barabanova, 2018). However, this rarely happens, as this example and the experience of other organic districts show. This paper explored how the grassroots campaign *Liberi dai Veleni*, born out of local CSOs and social movements, was able to act as an agent of change on local agri-food regulatory systems by actively and successfully engaging in redefining local regulations. This success is related to the movement's capacity to mobilize public action by focusing on transversal issues that strongly resonated with the local population. This is also in line with the principles of multi-actor governance processes, which involve dynamics of co-production, co-management and co-governance between private and public sector, the identification of common problems and of shared strategies to address them (Koopmans et al., 2018). In this paper, a successful case (the RPR and its approval process through citizenship labs) and an unsuccessful one (the organic district project) were described and compared. The RPR case demonstrates the effectiveness of a truly bottom-up approach in fostering the emergence of a common vision centred around sustainability values. In conclusion, initiatives aiming at territorial agri-food system change cannot become real vectors of transformation unless they strive to involve citizens from the beginning and to facilitate structural and behaviour changes. Collective and direct democracy-based action is necessary to ensure a sustainable agri-food future.

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LINKAGES BETWEEN AGRICULTURE AND FORESTRY IN FOOD PRODUCTION: BUILDING RESILIENCE OF RURAL COMMUNITIES

Mikelis Grivins, Talis Tisenkopfs, Anda Adamsone-Fiskovica, Emils Kilis, Sandra Šūmane

[a] Baltic Studies Centre, Latvia

1. Introduction

Agriculture and forestry represent two key types of land use in rural areas. Land use represents a broad field of academic research addressing questions related to land use conversion, conflicts associated with land use, land use management, land use and landscape management, and others. However, there is little evidence, apart from discussions related to traditional landscapes and biodiversity, explaining the interlinkages and factors linking the two most common land use types. The scarce evidence available on the ways how the two types benefit one from another illustrates that the separation between agriculture and forestry and the studies addressing the separation might be overlooking some essential aspects of the relations between the two. To be more precise, addressing the mutual interlinkages enabling the two sectors might help to engage with issues like rural development, regeneration of ecosystems, empowerment of local communities, improved sustainability, circular economy, improved economic performance and possibilities. Additionally, this might help to better understand the overall processes shaping agriculture and forestry.

Furthermore, the fields that do recognise these interlinkages and address the two land use types as supplementary have already illustrated the benefits of the approach. Most commonly these benefits are acknowledged in the context of maintaining biological diversity, for example, in the form of the rich mosaic of habitats associated with traditional agriculture of local communities (Guadilla-Sáez et al. 2019), in the form of greening payments and green infrastructure. Researchers have been reporting that there is a geographical overlap between the areas with the highest biological diversity and areas managed traditionally (Guadilla-Sáez et al. 2019). Traditional rural landscapes are associated with low intensity of anthropocentric disturbances, higher presence of traditional species and higher diversity of habitats. Europe, a continent that is almost entirely shaped by human intervention, serve as an illustration for this – biodiversity is almost exclusively dependent on traditional practices. Still, a set of socio-economic drivers are pushing these practices out. There is also evidence of agriculture and forestry being linked to improved household livelihoods by ensuring households access to different resources, through agricultural practices like agroforestry or through the potential of these interlinkages to ensure resilience. Thus both land-use types offer mutually supplementary economic, social and environmental possibilities, that can be fully apprehended only when they are interpreted in association one with another. Finally, there are also clear cultural interlinkages tying the two together. This dimension appears as traditional culture being embedded in a place and manifesting itself through a place. These interlinkages are apparent both at the micro-level – where people residing in a place manage their daily routine in a way that reacts to their surroundings as one total and at the macro-level – where global drivers of change always push the two land use types closer.

This paper discusses specifically the linkages between two of the land use types – agriculture and forestry. This paper suggests studying relations between agricultural and forested lands to develop new ways to conceptualising land use that would be more appropriate for the contemporary challenges associated with the two land use types. However, addressing people in place (an approach that would allow capturing the full spectrum of interlinkages) would be too broad to address the task this paper raises. Thus, a more specific empirical focus is selected - the paper looks at cases when people use food production, processing or distribution to link the two land use types. The paper illustrates that by linking the two types rural inhabitants diversify the production and structure producers' relations to consumers, improve their livelihoods and ensure the subsistence of communities, and even improve farmers' position in the agri-food supply chain. On numerous occasions, the people engaged with agriculture or forestry link the two types to enhance their prospects and current social position.

Although recognising that relations between agriculture and forestry should be reassessed at all levels, this paper concentrates on micro-level practices – on the daily experiences and management strategies of inhabitants of rural spaces. The paper relies on evidence gathered in Latvia. In Latvia, both high share of land is covered with forests and with agriculture. Furthermore, although the ownership of agriculture and forested land is continuously concentrating, a high share of smallholders remains both among forest owners and owners of agricultural land. Furthermore, evidence also illustrates that among owners of agricultural land, there is a higher share of owners of forested land. Thus there are natural ownership interlinkages that can be used as a starting point for the article. The article is not discussing the issues related to the domestication of wild products.

This paper starts with a short methodological overview. It then proceeds to discuss typical ways how the two land use types are linked and the conflicts observed between agriculture and forestry.

2. Methodology

The paper is based on data collected through several projects addressing ways how rural communities engage with wild products (TRUST: Innovations in Non-timber Forest Products: Towards RUral development and Sustainability), the role of small farms in regional food systems (SALSA: Small farms, small food businesses and sustainable food and nutrition security), and the institutional arrangements structuring agricultural markets (SUFISA: Sustainable finance for sustainable agriculture and fisheries), the role of innovations in creating sustainable production and consumption (SINFO: Social Innovation in Food Provision: Pathways to Sustainable Production and Consumption). None of these projects was addressing relations between forestry and agriculture directly. However, this was a theme that kept to be reappearing through the in-depth interviews conducted for these projects. This paper combines evidence from these projects and presents them to illustrate how the two land use types are interlinked. Specifically, it looks at the explanations provided in these interviews and uses them to build a coherent explanation of the relations between the two land use types. Additionally, each of the projects addresses a somewhat different target group – TRUST among other things discusses both small and large firms benefiting from wild products; SALSA engages with small farms and small food businesses; SUFISA allows engaging large farms; SINFO covers innovative food initiatives. Together these projects offer a broad overview of the way how forestry and agriculture are linked by a large set of actors.

3. Merging the two land use types

From the interviews conducted with farmers and actors who have built a business out of engagement with wild products, we identify four strategies that are used to link forests and farming. The strategies presented here are those that are allowing actors engaged with forests and agriculture to profit from the connections between the two land use types. This means that the cultural connections linking the two land use types farmers might have presented during interviews are not considered here. However, there is a need to discuss the cultural connections at least superficially. Mainly this is because how widespread these practices are. Most of the farmers interviewed if not all were also suggesting that they have been harvesting some non-timber forest products from the wild. Foraging is a common practice in society in general – to collect wild products. It is even more widespread among farmers. The same thing can be said about people interviewed for their engagement with foraging – all of them were reporting to have at least a small plot where they were growing food for household consumption. Thus, being engaged with both is deeply rooted in the culture and meals served on the tables of rural inhabitants are continuously linking the two land uses. Any interpretations of the interlinkages agriculture and forestry might have, should take into consideration the deep cultural rootedness farming and foraging hold in society.

When it comes to commercial ties between the two land use types, two axes captures the difference between the various strategies how the two are interlinked. The first axis is the regularity of the connections. The second axis illustrates the commercial significance of established connections. Thus, some of the identified strategies choose to link the two land use types irregularly, and the connections are not economically significant to actors linking the two. In other cases, the opposite happens - rural entrepreneurs choose to link the two regularly, and this linkage is crucial for their business. Two additional things have to be mentioned here. First, the interpretation of connections presented here is just one of the way how these interlinkages can be presented. Second, the paper does not provide information on how widespread the strategies are.

3.1. The four strategies of connecting forestry and agriculture

The first group to mention here are those irregularly connecting agriculture and forestry while the connections they are creating are of low importance - the connections between the two land use types could be broken, and that would have only a marginal effect on the enterprise. Most typically, this is the case when the connections between the two land use types are established for marketing purposes. Some of the respondents selling harvest from their garden were also offering seasonal products from the wild to their customers. Interestingly, the same thing could be observed among foragers as well. People professionally engaged with wild product foraging and selling were using products from their gardens to diversify their offer. These were, however, mainly small farmers or small-scale wild product traders. However, their motivations are something worth discussing. For some of them, this was a marketing opportunity – a possibility to present a more diversified set of sold products.

Furthermore, in an interview with a restaurant owner, the respondent stated, that they would expect that the small farmer who was selling them their homegrown products, would also supply the restaurant with seasonal wild products as well. Thus, we might assume that the diversification of products is not so much a traders marketing imagination, as it is reflecting consumers' expectations. For consumers, all that is perceived as local produce comes from one source – a rural farmer. Consequently, we could suggest that this particular way of doing business is representing a cultural image of what does it mean to be a small commercial farmer or forager.

The same strategy, however, is used by a group of less sophisticated traders as well. Those that are using the whole diversity of the products available to them for marketing purposes in most cases have well developed commercial channels to sell their products. They know their customers and have a clear grasp of their needs. However, there are also those actors who benefit from agriculture and forestry in a less organised fashion. This group of actors have low income and does not have the means to introduce a permanent income source. They are fighting this by looking for all the possibilities of trade that emerge to them. For example, some of them were selling wild products using roadside stalls, they used the same stalls to sell midsummer wreaths during the time of summer solstice, or they are selling excess produce from their gardens. Yet they are not looking for how to convert their trade into something stable. It is rather sporadic. It also seemed that this group was more reliant on wild products. Probably, it can be explained with the nature of wild products – they are openly available, and even when engagement with these products are regulated, it is still hard to monitor how are these regulations implemented.

What characterises this group is that the engagement with forests is unstructured. It is impossible to be unstructured about farming. Nevertheless, it is possible when it comes to engagement with forests – one can benefit from forests without building complicated social structures to do so. Also, typically, land use is profoundly affected by infrastructure and population density. These interlinkages between the two are not affected by the two factors. Finally, these relations are not putting the two land use types in conflict.

The second type of strategy to mention here is characterised by irregular relations, which nevertheless are crucial for actors connecting the two land use types. The first thing to mention here is that in the empirical material, there are no cases, where relations as just described would have been introduced by actor, whose primary interest is forestry. All of the relations in this group were initiated by farmers. In fact, this should not come as a surprise, because agriculture and forestry operate in two very different time frames, and while forestry can be associated with the irregularity of engagement, agriculture demands regular attention. In this case, the significance of the relations is not associated with the products forest can provide, but with the particular services, forest grants access to. There are three ways how we observed these relations in our inquiry. First, infrastructure crucial to agriculture might be located on forested land. For example, melioration systems commonly are crossing land covered by forests. This ensures that in farmers mind the two land use types interrelate. Second, forest operates as a cash reserve accessible in difficult periods or when investments have to be made. Thus, instead of looking for a bank loan, farmers use forests as cash deposit that they withdraw when needed. This approach allows farmers to become more resilient. Furthermore, this allows farmers to be more independent from financial institutions.

Additionally, there are few opportunities for small or medium-sized farmers to access funding. In most cases, actors providing funding to farmers are working with large farms ignoring the smaller ones. On top of that, it seems that many farmers are preferring to distance themselves from taking loans. Consequently, having a forest that can be capitalised and invested in the farm is both a way how to overcome the cultural distance smaller farmers has towards burrowing as well as a way to overcome structural challenges observed in relations between banks and farmers. Finally, the third way how this strategy plays out is through the conscious use of ecosystem services, the other land use type provides (such as protection against sudden rainfalls or winds).

The third strategy to be discussed here is characterised by regular interlinkages that are of crucial importance to people maintaining these interlinkages. In practice, this though can mean very many things. For example, some small farmers reported that they benefited from the particular surroundings of the farm – either by using materials from the forest on the farm (such as firewood), or by using landscape in the advantage of farming. Some other farms used closeness of wooded areas to structurally and permanently diversify their business. There are cases of farmers who have opened guesthouses using their nearby forests to introduce additional activities for guests. There is also evidence of the opposite – where the farm mainly sells wild products while the farm is just space that can be rented to tourists willing to enjoy the rural landscape. Also, among the interviewed people, there are respondents, who have benefitted from the closeness of forest by introducing new farming practices. For example, a respondent mainly working with arable crops some years ago decided to introduce goat farming. He used the wooded areas nearby as pastures for the goats. The farmer claimed that wheat farming, although highly profitable, is also unpredictable and thus, income diversification was crucial to him.

However, probably the most critical group using this strategy are farmers, that have up-taken farming in order to introduce a commercially successful wild product trading enterprise. The most obvious evidence of this connection comes from people working with herbal teas; however, other cases exist as well. These people domesticate what they can and gather from the wild what is either impossible or too challenging to domesticate. Consequently, they have farms that simultaneously operate as conventional farms, yet that is also looking for a way to harvest from the wild. The employees of these herbal tee farms are trained to harvest what has grown on the farm as well as the products that grow in the wild. On one occasion, the farmer was supplementing these arrangements with an apiary he held on the farm. Because of the herbal teas, he had many flowers surrounding the farm. Farmer used the unique surroundings of his farm to diversify their income sources further. It is worth noting here, that those who have decided to pursue this way of operating on their farm shows high competency in the way how the market works and how they can sell their products. Although in broad terms they could be classified as small or mid-sized farms they are exceptionally well connected to global markets, many of them are certified and sell only organic produce, they also show deep knowledge of ways how to market their product to customers and – many of them have managed to install in farm at least some processing equipment, that allows them to sell the product for higher price.

Finally, some linkages are regular but with low significance for actors' overall performance.

4.2. Conflicts emerging between the two land use types

The closeness of the two land use types is not just manifesting through positive experience – it can cause tensions as well. Many of the possible conflicts have been widely discussed in the literature addressing land use. However, the presented interlinkages between agriculture and forestry should be used to add a layer of meaning to the tensions described in the literature. The following examples should be seen as an illustration that the conflicts that might seem to be illustrating a crack between the two major land use types in Latvia are not always there. The observed conflicts are instead an attempt to change the behaviour of particular groups. Furthermore, often, these groups that are meant to be persuaded are standing far from real engagement with agriculture or farming.

The first tension to be presented here is associated with conversion from one land use type to another. Availability of land and especially agricultural land has been an aspect stressed in interviews with farmers. Although to be fair, this claim has rarely been raised by smaller farmers. Instead, it has been often raised by large farmers who, as mentioned before, has much easier access to credit. The argument goes that much of the land is slowly taken over by shrubs and consequently are taken over by forests. This argument fits well with pan-European discussion on land conversion. However, as illustrated by data, most of the farmers own at least some forested land; thus, probably they do not have any objections towards wooded land per se.

Furthermore, Eurostat Land Use data is showing a decrease in the share of land used for agricultural purposes, yet only marginal increase can be observed for the share of land used for forestry. Instead, the fastest growth can be observed in the share of land unused and abandoned (Eurostat, 2019a). On top of that, it is not the land used for crop farming that has shrunk during the last decade. On the contrary, this particular land cover has grown its share in Latvia. Instead, the most notable decrease of share can be observed for grassland (Eurostat, 2019b) – a land cover that usually is associated with a smaller scale of activity and herbivore farming. The decrease of grassland can be associated with a substantial decrease in the number of small dairy farms observed during the last decade. Consequently, the real conflict is not so much between forestry and agriculture, as it is between the group using rural areas for production and those, that are not doing that.

The second conflict between agriculture and forestry is associated with the presence of wildlife. Forests, being a home of wild animals, are often presented as a threat to farming. The argument suggests that if left unchecked, the population of wild animals will reach a level, where it will become a threat to local businesses. Farmers were claiming that due to the wild animals, farmers are losing their harvests (an argument that can be heard everywhere where farming has to coexist with forestry). Thus, in this regard, the closeness of the forests is presented as a threat to farmers' commercial interests. In some interviews, this question is also interpreted in the light of possible diseases wild animals might be carrying around. Global food scandals and the recent outbreak of African swine flu in Latvia have just strengthened these arguments. Still, even in this case, the accusations are not as much an attack against forests, as it is an attempt to reshape the overall attitudes towards various models of forest management. Furthermore, as it will be shown in the following paragraph, it was not even a clash between governing institutions responsible for the two sectors – the same Ministry overlooks both forests and agriculture. It was instead a clash between groups regarding rural territories as a source of income and those, that are supporting greater environmental protectionism.

Data on wildlife as presented by Ministry of Agriculture illustrates that indeed after Latvia regained independence, the number of wild animals in Latvia's forests started to grow (Ministry of Agriculture, 2019). Furthermore, the quota for animals that allowed to be hunted during the last decade of the 20th century and the first decade of the 21st century was growing much slower than the number of animals. This led to farmers vocalising their challenges. This outcry was amplified by farmers organisations, the Ministry and the spread of the African swine flu. Yet it was directed only towards public opinion and environmentalist groups. There was no common response from forest owners. However, since then, the situation has changed drastically. Although the population of some animal species have continued to grow – some haw witnessed a sudden sharp drop in numbers. Meanwhile, those species whose population have continued to grow, in most cases have also witnessed a significant increase in hunting quota (equivalent to the growth paste in absolute numbers). However, for a number of species, the number of hunted animals does not catch up with the quota. Thus, although the preconditions to maintain the wild animals' populations have been introduced, it is the social aspects that limit their successful implementation.

With that being said, it is not the intention of this paper to discuss the optimal number of wild animals in Latvia's forests. Instead, the previous paragraph should be interpreted in the light of relations between forestry and agriculture. It shows that the challenges associated with the wilderness is not a challenge agriculture poses to forestry. It is instead a challenge posed to forest management approaches, an attack on environmentalist groups and an attempt to engage the hunter community. It is an attempt to reshape the ways how broader society perceives the best management models for forests.

Finally, the third issue of generating tensions is the use of infrastructure. On the one hand, this is relatable to melioration that has been discussed earlier. On the other hand, this is related to roads located around rural areas. There have been public accusations regarding who causes more damage to public infrastructure. Many actors, including farmers, have been pointing fingers at enterprises lodging timber. Clearly, these actors are not without a fault. Still, farmers as well have large machinery that moves across the public roads much more often than the machines operated by lodging enterprises. It can be suggested, that both sectors are putting stress on public infrastructure that the infrastructure cannot hold. However, it must also be recognised that much of the problem is associated with the low quality of the roads – and insufficient public budget allocated to the maintenance of road infrastructure. Furthermore, the public bodies responsible for forestry has allocated a notable share of their budget to build and rebuild roads. Again, it is worth to remind that the article is not giving a judgement on how to assess the intensive road-building initiative in Latvia's forests maintaining by the department responsible for forests. There have been strong arguments for and against it. The article is instead aiming at illustrating that the critique each sector might have one for another (the aspects of critique that are illustrated by interviews) are not really as straight forward as they might appear. This conflict should probably be interpreted as an illustration that nobody is willing to take the blame for the bad condition of rural public roads, yet everybody willing to point out that something needs to be done with the issue.

The three presented aspects of portrayed conflict should be interpreted in the light of the fact that farmers are more commonly forest owners that society in general. They are benefiting from both sectors, and thus they are not inclined to facilitate conflict between the two. Furthermore, as this sub-chapter illustrates, although some of the issues characterising relations between the two sectors could be framed as a conflict, most likely, it is not. It is rather a conflict with some other groups of actors. The interests of the two sectors are too intertwined.

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FOOD SECURITY IN THE MEDITERRANEAN BASIN WITH AN ANALYSIS IN MACHINE LEARNING

Michel Mouléry[a], Esther Sanz Sanz[a], Claude Napoléone[a], Davide Martinetti[b]

[a] INRAE, Ecodéveloppement, France

[b] INRAE, Biostatistique et processus spatiaux, France

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INTRODUCTION

The Mediterranean region is a biome of specific richness of world importance (Underwood et al., 2009), where population is constantly growing (from 446M in 2000 to 570M in 2025 – geoconfluences, 2014) [58], urban development increases, while only 14 % of the region can be devoted (consacré) to agriculture and food production (118 millions of hectares – Zdruli, 2014).

The problem is complex, Mediterranean agricultural systems are heterogeneous (from single-species industrial production to traditional small farms), faced with the necessarily that determine the developments of the agricultural sector (market conjunctures, national and international policies of regulation of uses or production standards), makes the consensus needed for public action more difficult (Smith, 2009; Lambin and Meyfroidt, 2011).

Today, urban policies need to incorporate food security considerations and focus on building cities that are more resilient crises. There is a growing recognition of intra and peri urban agriculture and forestry as an important strategy for climate change adaptation and disaster-risk reduction (Lwasa, Dubbeling,2015). But for the moment food insecurity is still a major global concern for example in sub-Saharan Africa, the number of people suffering from hunger is estimated at 239 million, and this figure could increase in the near future (Albert Sasson, 2012)

In this way, to try to understand all this system, there is a need a tool for representation multi-scalar analysis to determine the evolution of agricultural systems at the local territory level and their constraints.

In this perspective was established a spatial database at the INRAE d'Avignon (Ecodéveloppement) with high resolution (8-10km), homogeneous on the Mediterranean basin: between 2005 and 2015 or are detailed the topography (slopes, altitudes, etc.), land use (urban area, vegetation, crops, bare soils, forests), bio-climatic elements (temperatures, rainfall, etc.) and socio-economic elements (population, agricultural practices, etc.).[59]

we will ask ourselves the question: which variable the most representative of the database explains the production of wheat?

METHODS

Borders

In the first place, defining the border or borders in the Mediterranean is an arduous study, and differs according to the research disciplines. We can mention some examples of work in ecology for the environmental stratification in Europe (Metzger et al., 2005) (cf. figure 1) and in geographically oriented with (Malek, Ž., & Verburg, P, 2017) (cf. figure 2).

[58] http://geoconfluences.ens-lyon.fr/actualites/veille/parutions/world-urbanization-prospect-2018

[59] https://hal.archives-ouvertes.fr/hal-01907477

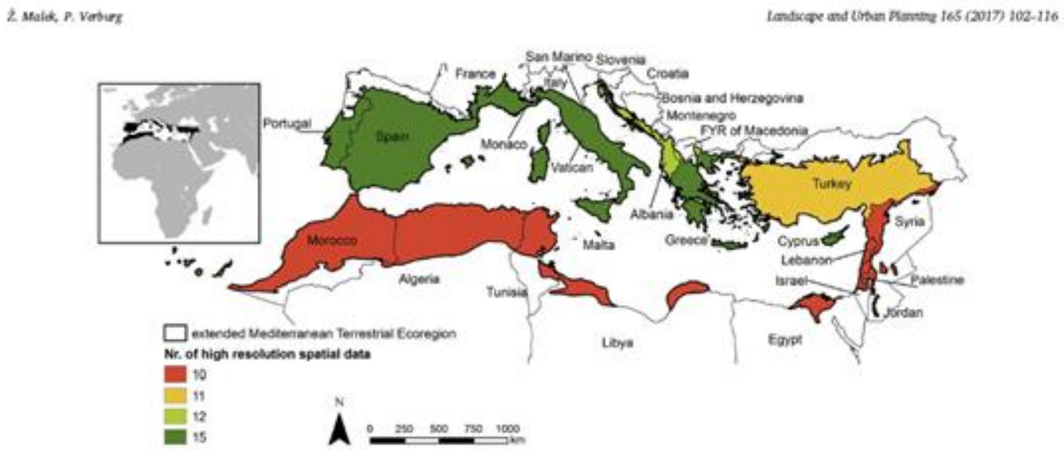

Figure 1 : The méditerranean border in Géography of Malek and Verburg.

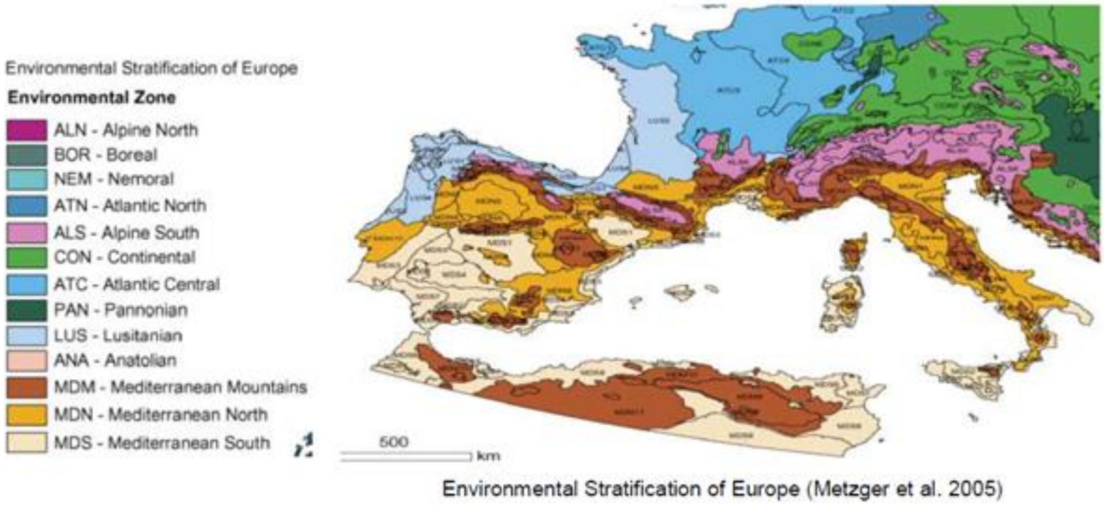

Figure 2 : The méditerranean border in Ecology of Metzger et A.l

In our case, the Mediterranean has been redefined in three area.

In first, for the North, the border is based on the recent work of the research project « Divercrop [60]» , by using the definition of the European environmental zones made by Metzger et al including the Southern Alpine zones located in continuity of the Mediterranean zones except the Carpathian Mountains. On the South, approximately, we have focused on the arid zones using the map of rainfall (zones < 25 mm (Icarda,2011), (cf. figure 4). This area is interesting subject to extreme climate temperatures

[60] THE DIVERCROP research project (N° ANR-16-ARM2-0003-01) funded by Arimnet2 program (FP7 – ERA-NET no. 618127; Mediterranean Agriculture .

Finally, in red color we name the «Intermediate zone» (cf. figure 3) between North and South on the southern and eastern edge of the Mediterranean, with slightly more favourable rainfall than in desert areas (cf. figure 4).

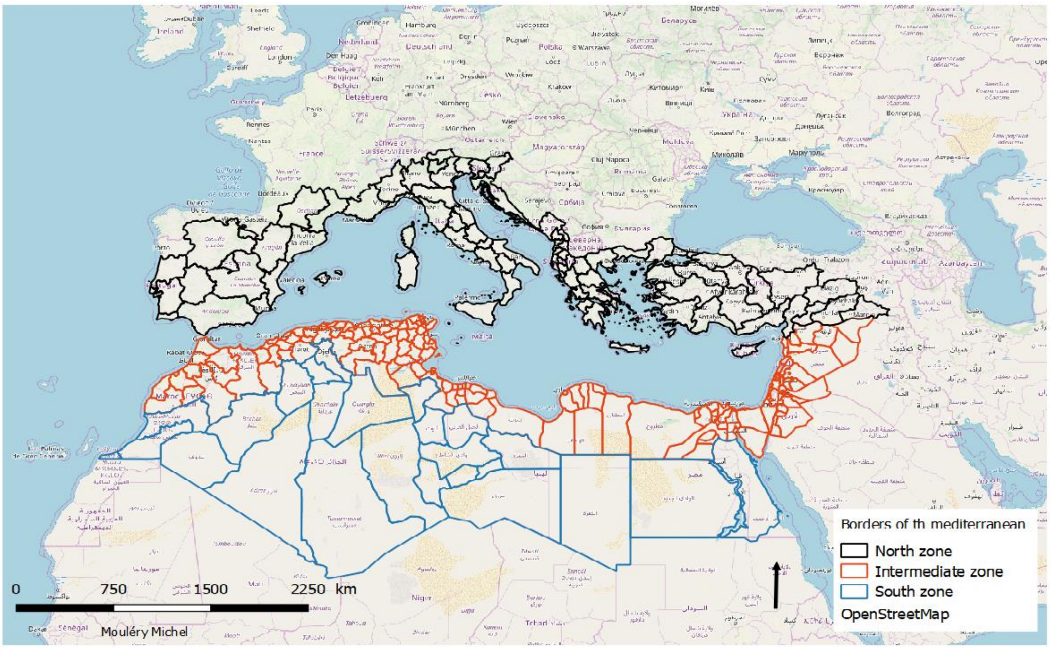

Figure 3 : Mediterranean border

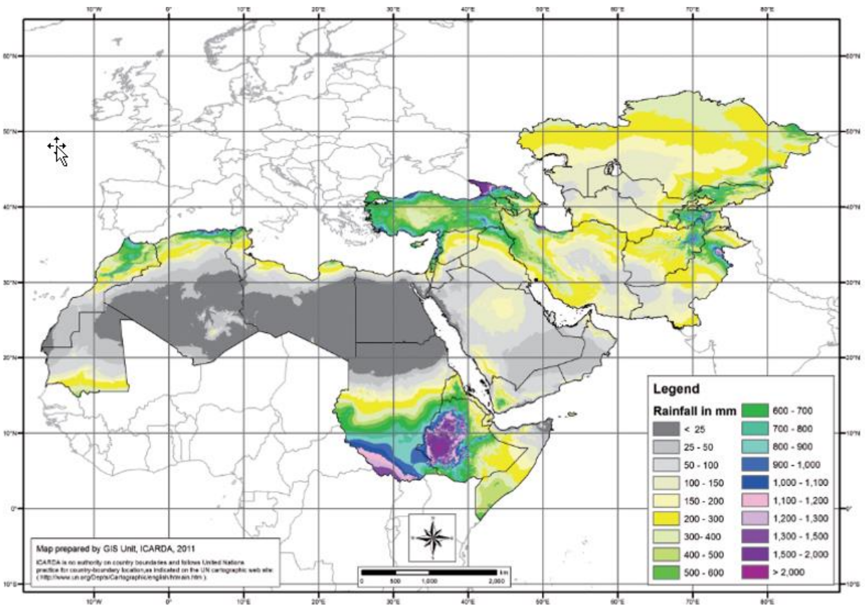

Figure 4 : Rainfall zones of CWANA region

Once we have roughly defined the borders, we have built up a homogeneous database [61] at the same resolution based (Mouléry , Napoléone , Martinetti , Sanz Sanz , 2019) on data sources such as :

[61] This database is owned by INRA (France), issued from the DIVERCROP research project (N° ANR-16-ARM2-0003-01) funded by Arimnet2 program (FP7 – ERA-NET no. 618127; MediterraneanAgriculture); see https://hal.archives-ouvertes.fr/hal-01907477. For all dissemination and use, contact

The SPAM agricultural land use data (You et al. 2014), which is based on agronomic models, estimates crop distributions within pixels at a 10 x 10 km grid-cell resolution resolution. For each crop class (around 40) are attached indicators informing practices (intensity of irrigation, use of inputs), as well as information (including the past dynamics of agricultural uses) from national agricultural statistics from the various countries around the Mediterranean.

FAO [62] data on livestock.

With regard to the city and natural areas, we used information from the Modis land use at the University of Leuven (300 meters resolution) and the mapping of protected areas proposed by the IUCN. We have supplemented these sources with the HYDE database (Klein Goldewijk, 2011) which provides information on the distribution of the urban and rural population and LANDSCAN on the general population in a more precise way.

Field variables have been integrated for soil quality with the Harmonized world soil database source or with slope topography and elevation (Global Digital Elevation Model) variables.

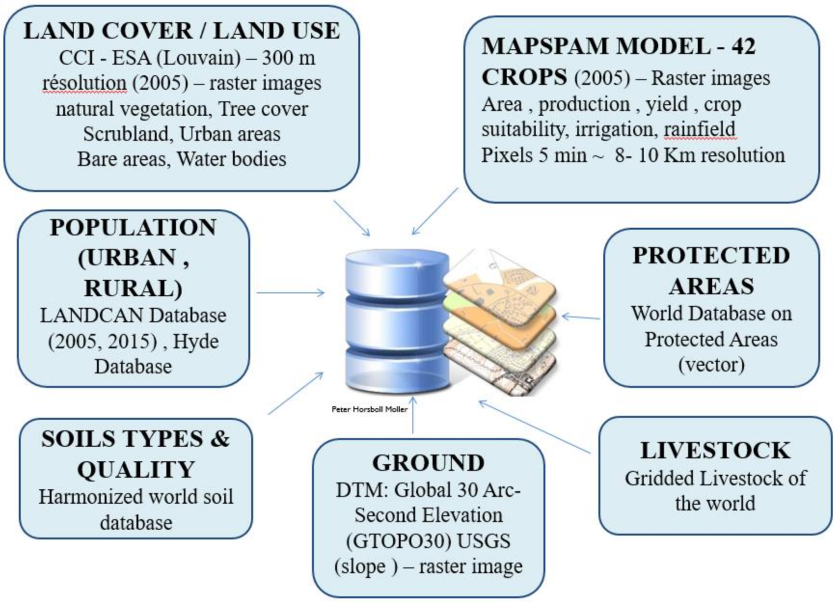

Figure 5 : Divercrop database

We have overlaid and split the database informations (cf. figure 5) on each border, before to launch the work in machine learning.

Machine Learning

Thanks to the computing power of computers, it is now possible to generate more and more efficient calculations, with large amounts of information in a database. In statistics, models in machine learning are increasingly used and are based on statistical approaches to give computers the ability to "learn" from data, that is improve their performance in solving tasks without being explicitly programmed. In

marta.debolini@inra.frorclaude.napoleone@inra.fr

[62] Food and Agriculture Organization of the United Nations

our case to explain the wheat production, we used the library MLR [63] (Machine learning) with the software R, it encapsulates different statistical models.

We have selectionned five statisticals regression models the most known: Network neural, Support vector machine (SVM), Earth (regression splines), Random Forest, PLS (Partial Least Squares). Each border (North, South, intermediare zone) contains the topography, the bio-physical, land use, bioclimatic, socio-economic information of the divercrop database. In machine learning, for referenced the target variable wheat production, and integrated all the data, we used a calibration function makeRegrTask. For the configuration of the statistical models, we use the function makeleaner , that reference the name of the statistical models. To have a better quality in our model, we used a permanent train-validation splitting (function makeResampleDesc), a dataset can be repeatedly split into a training and a validation datasets. This is known as (CV) cross-validation (cf. figure 6) with 5 itérations. This sequence below has been executed for each border.

task_train_subset <- makeRegrTask(id = "best model",data = North_data, target = "p_ta_whea") rdesc=makeResampleDesc("CV", iters = 5 , stratify = FALSE) lrns2=list(makeLearner("regr.earth"),makeLearner("regr.ksvm"),makeLearner("regr.randomForest"),makeLearner("regr.lm"), makeLearner("regr.nnet"), makeLearner("regr.plsr")) bmr = benchmark(lrns2, task_train_subset, rdesc,show.info = FALSE)

Figure 6 : Cross Validation https://en.wikipedia.org/wiki/Cross-validation_(statistics)

Finally, the function benchmark determinate the best model (variable bmr), looking at the variable MSE (mean squared error), below in this case for the intermediate zone. The lower the MSE the better (cf Table 1)

Model	Leaner	Mse.test.mean
regression splines	regr.earth	4 882 362
Support vector machine	regr.ksvm	16 306 891
Random Forest	**regr.randomForest**	**2 235 332**
simple linear regression	regr.lm	4 971 280
Neural network	regr.nnet	14 512 632
Partial Least Squares	Regr. Plsr	4 958 886

[63] Bernd Bischl, Michel Lang, Lars Kotthoff, Julia Schiffner, Jakob Richter, Erich Studerus, Giuseppe Casalicchio, Zachary M. Jones; 17(170):1−5, 2016. The mlr package provides a generic, object- oriented, and extensible framework for classification, regression, survival analysis and clustering for the R language. It provides a unified interface to more than 160 basic learners and includes meta-algorithms and model selection techniques to improve and extend the functionality of basic learners with, e.g., hyperparameter tuning, feature selection, and ensemble construction. Parallel high-performance computing is natively supported. The package targets practitioners who want to quickly apply machine learning algorithms, as well as researchers who want to implement, benchmark, and compare their new methods in a structured environment.

Table 1 : Example best model Random forest for the intermediate zone

Whether it is north, south, intermediate zone, the best statistical model has always been ramdon forest. We use the function « selectFeatures » to have the most representative variables for each border in relationship with the wheat production (Figure 7). We use the sfs method [64] and launch the function analyzeFeatSelResult to have the most representative variables that explain the wheat production.

Leaner_intermediate_zone=makeLearner("regr.randomForest")

ctrl=makeFeatSelControlSequential(method = "sfs", alpha = 0.02)
 # Select features
rdesc = makeResampleDesc("CV", iters = 5) sfeats = selectFeatures(learner = Leaner_intermediate_zone, task = task_train_subset, resampling = rdesc, control = ctrl,show.info = TRUE) res<- analyzeFeatSelResult(sfeats)

North (Europe)	Intermediate zone (North west Africa)	South (desert)
Rooting conditions	Cropland rainfed - Tree or shrub cover	Density population
Cropland Rainfed (Herbaceous Cover)	Precipitation of Coldest Quarter	alti_min
Precipitation of Warmest Quarter	Max Temperature of Warmest Month	chicken
Temperature Seasonality	cattle	Precipitation of Driest Quarter
Mean Temperature of Wettest Quarter	Goats	Rooting conditions : Soil textures, bulk density, coarse fragments, vertic soil properties and soil phases affecting root penetration and soil depth and soil volume
Altitude moy	chicken	Precipitation of Wettest Month
Cropland irrigated or post-flooding	Mean Temperature of Coldest Quarter	podzoluvisols (pd): Acid soils with a bleached horizon penetrating into a clay-rich subsurface horizon
Precipitation of Coldest Quarter	Cropland irrigated or post-flooding	Cropland irrigated or post-flooding
Precipitation of Driest Month	Cropland rainfed - Herbaceous cover	goats
Cropland rainfed – Tree or shrub cover	Annual Precipitation	

[64] Method = "sfs" indicates that we want to conduct a sequential forward search where features are added to the model until the performance cannot be improved anymore. The search is stopped if the improvement is smaller than alpha = 0.02. (https://mlr.mlr-org.com/articles/tutorial/feature_selection.html)

Mean Temperature of Warmest Quarter	Rooting conditions	
slope_5, slope =10%	sheep	
Cambisols	Fluvisols: Young soils in alluvial deposits	
Isothermality	Temperature Annual Range	
Workability	Precipitation of Driest Month	
Temperature of Coldest Quarter	Precipitation Seasonality	
Precipitation Seasonality	Alti moy	
cattle		
Tree cover needle leaved evergreen open		
Oxygen availability to roots		

Figure 7 : Best variables for the wheat production with Random Forest

Results

In the Mediterranean desert, relative to our grid (cf. figure 7), the variable density population shows that is related to wheat production. This leads us to believe that, close to cities, wheat farming is omnipresent. We assume that it is a nourishing agriculture of the city, with markets nearby. Studies of food deserts assign a pivotal role to 'the proximity and density of retail food outlets in specific neighborhood as markers of access to affordable (Shannon 2013, Jane Battersby Jonathan Crush, 2014). In Algeria, wheat, which has always been grown on small areas in the palm groves, has until now been used exclusively for own consumption (Bisson, 2004). This complementary but essential crop is justified from the agronomic point of view, because wheat is one of the crops best adapted to the Saharan climate, and consumes three times less water than palm (Tayeb Otmane et Yaël Kouzmine, 2013). The importance of the water is mentionned like cropland irrigated or post flooding (the best variable), and the precipitation of warmest quarter). Rather, it is subsistence agriculture, or low-yielding agiculture close to the city in medium-sized markets.

In North Africa, There are more variables that emerge from it compared to the southern area (Figure 7). Random forest algorithm in this area, detects several bio-climatic variables like temperature, precipitation and the soil quality. The livestok are important, in general wheat production is more than an average altitude indeed cereal production is more in the mountain ranges of North Africa. For example, the Algerian Highlands are the main cereal areas of Algeria. Bordered to the north by the Atlas Tellien and to the south by the Atlas Saharien, these highlands travel diagonally across Algeria to the North-West of Tunisia at an average altitude of 1000 m. (Beauval, 2017).

The livestock are confirmated by the studies of ICARDA (Pala et Al,2019), « Wheat and barley are the main crops, with sheep and goats as main livestock, although many farms may have some cattle. Farms under private smallhold-er ownership, fairly productive, diversified, and well managed »

In our european zone, the bio-climatic variables are too very important, the livestock are less important compared in Africa for the wheat production. The altitude and the slope are important, like the cattle where geographical areas in mountain areas appear to be targets. The population density near the city is not a key factor, indeed the production of wheat is grown on large areas away from the city. The common agricultural policy did not favour cereal farming near cities on small areas.

Conclusion

In the end our work can be discussed, criticized whether on the resolution of the pixel between 8 and 10 km, different data sources that have been homogenized in a database, the configuration of the functions in statistics or the cross validation method threshold set at 5. It's the first time that a work presents a database with a large amount of information, on a very large scale and associated with a machine learning method to find the «ideal» statistical model.

In conclusion, at this scale, there is not too much difference on this broad scale between the north of Africa and the European zone, the contrast comes more from the desertic zones or the production of wheat is correlated with the population. It seems that the access is more difficult and therefore it seems that generally it is an agriculture of proximity, of self-consumption close to the cities, with the problem of water.

Even if these three areas have very different climatic, social and political differences (CAP aid for Europe), cultural, agronomic, this work shows us a first trend in our case on wheat production. But these first original works, enriching on a large territory like the Mediterranean, with different zones based on the machine Learning, give us a first general trend, a first understanding to express the production of wheat, which allows us to reflect on the movements of these Mediterranean territories.

However, this work is exploratory but it makes us reflect on the outcome of certain variables which can be studied more deeply in a future work.

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A JUST TRANSITION? JUSTICE PRINCIPLES RELEVANT TO FOOD SYSTEM TRANSITIONS

Annemarieke de Bruin[a], Imke J.M. de Boer[a], Niels Faber[b], Gjalt de Jong[b], Katrien J.A.M. Termeer[c], Evelien M. de Olde[a]

[a] Animal Production Systems group, Wageningen University & Research, the Netherlands
[b] Centre for Sustainable Entrepreneurship, University of Groningen, the Netherlands
[c] Public Administration and Policy group, Wageningen University & Research, the Netherlands

Abstract: In response to social and environmental injustices perpetuated by the dominant productionist view of the food system, an increasing number of initiatives are trying to make local food systems more sustainable and more just. These initiatives show which alternative food systems are possible and with the right propelling mechanisms they can help speed up the transition process towards a sustainable and just food system. However, it is important to also reflect on how these initiatives and propelling mechanisms contribute, or not, to a just transition of the food system.

The concept of ‘just transitions’ was developed within the context of energy transitions and climate justice and brings together concerns related to distributive, procedural justice, and social justice for those working in and/or depending on the current dominant system. Within the food systems literature, justice plays an important role, including in the work related to food justice, food sovereignty and food security. However, few studies have adopted a ‘just transitions’ lens and it is unclear which principles of justice are particularly relevant to reflect on the justice of food system transitions.

We reviewed the food systems literature to identify which principles of justice were used to assess justice implications of food system initiatives that had happened or were ongoing. We selected and analysed 138 papers. These papers covered very different types of initiatives in terms of scale - ranging from regional food networks to very local urban agriculture initiatives – and in terms of underlying values - with some initiatives strongly rooted in food justice and others in ecological sustainability.

Across this diversity of initiatives the review identified a number of principles related to distributive, procedural, and social justice relevant to food system transitions. Distributive justice principles included a.o. equality of outcome, equality of opportunity, and sufficiency. Procedural justice included a.o. equal opportunity to participate, legitimacy, transparency, and autonomy. Related to social justice, the papers discussed the principle of redistribution of costs and benefits, and of power, specifically to marginalised communities, to those with certain roles across the food system, to those who (have) suffer(ed) negative consequences of the food system, and to non-humans.

The identified principles encourage a broader debate about the justice implications of food system transitions and can help food system initiatives, and propelling mechanisms, to reflect on the justice of the transition process itself.

LOCAL FOOD SUFFICIENCY IN THE MEDITERRANEAN BASIN - ENABLING AND CONSTRAINING FACTORS

a Esther Sanz Sanz, Carolina Yacamán Ochoa b , c Lamia Arfa , d Rosalia Filippini

a INRA Ecodéveloppement - UAPV, Domaine St Paul, Site Agroparc 84914 Avignon cedex 9, France
b Universidad Complutense de Madrid, Spain
c Institut National de Recherche Agronomique de Tunis, Tunisia
d Università degli Studi di Milano (UNIMI), Italy

Abstract: Current land use is causing unprecedented changes in agriculture mainly because of urban sprawl, in particular on coastal or metropolitan areas. These main changes are not independent and act in a feedback chain: disturbance of traditional agriculture surrounding urban areas due to cities expansion that leads to the development of a market-oriented agriculture for the globalized market, while new forms of agriculture linked to the city are created. In other words, the new urban food agenda is addressing global challenges and developing place-based solutions as a means to enhance reliable food supply at a local and regional scale. In this context more research is required to address challenges of global urbanization and metropolitan growth and to develop place-based solutions The aim of this session is to identify key enabling and constraining factors of local food sufficiency (i.e. proportion of locally grown food which is consumed locally) as a means of food security, especially to hone in on options to deepen and broaden a transformative urban food agenda. Therefore, we invite papers to present and discuss current urban food systems dynamics including both land use and network interactions. Case studies involving stakeholder perception or/and statistical approach of the determinants of local provision of locally grown food products along the three major levels of the supply chain (agricultural production, food chain organization and commercialization) are welcome. This session could benefit from the contribution of some local case studies concerning some specific products, developed in the framework of the Arimnet2 project DIVERCROP (Land system dynamics in the Mediterranean basin across scales as relevant indicator for species diversity and local food systems). With these case studies, we are able to characterize the drivers of the re-localization of urban food systems in term of policy, processing infrastructure and social innovation. However, we would like to enrich the session with other papers focus on non-Mediterranean area.

"I AM SURE THEIR VET IS THEIR MAIN ADVISER": KNOWLEDGE NETWORKS AND INNOVATIVE POTENTIAL IN SHEEP FARMING

M. Sautier[a], A. Somera[b], R. Rostellato[a,c], Pauline Ly[a], Yann Labrune[a], J.M. Astruc[c], P. Jacquiet[d]

[1] GenPhySE, Université de Toulouse, INRAE, ENVT, F-31326, Castanet Tolosan, France
[2]CDEO, Quartier Ahetzia, 64130, Ordiarp, France
[3]IDELE, Institut de l'élevage, Castanet Tolosan, France
[4]UMT Santé des Petits Ruminants, UMR INRAE/ENVT 1225 IHAP, Ecole Nationale Vétérinaire de Toulouse, France

Abstract

Current health management practices in livestock farming are not sustainable, mostly because they select pathogens resistant to treatments. If integrated pest management is a common and accepted practice in agriculture, its animal counterpart is way behind. In other words, integrated health management in animal production embeds in so few practices that farmers do not recognize and advocate it per se. In this context, research and development is needed 1) to identify and design innovative livestock systems and management tools in line with integrated health management principles and 2) to better understand innovation dynamics in livestock farming.

This article contributes to the latter. The aim of our study was to explore how knowledge and information circulate among farmers, and between farmers and non-farmer stakeholders around the theme of parasitism control. For this purpose, we carried out a questionnaire-based survey among 536 dairy-sheep farmers in the Pyrénées-Atlantiques (France).

We analysed knowledge networks for parasitism control by listing whom farmers talk to when dealing with parasitism control. We identified the kind of individuals likely to be contacted by farmers depending on the farming system and the farmers' representations. Results are discussed in terms of implications for developing integrated health management programs that take into account the diversity of health management actors and farmers identities.

Introduction

Transitions towards agroecological farming systems calls for higher autonomy of farms (Dumont et al. 2016) and decreased the inputs needed for production (Dumont et al. 2013). This advocate for ruminant livestock systems based on grasslands (Soussana et al. 2014). However, several technical barriers come with managing grassland-based livestock systems. Among them are gastrointestinal nematodes, round worms from 4 mm to 3 cm to which any grazing animals are exposed (Charlier et al. 2017). Infestation risk increases with warm and wet conditions; the same as the one needed for grass growth. The life cycle of gastrointestinal nematodes divides in two main phases: one on grasslands and the other in the digestive tract of the host. They damage intestinal tissues and feed with host's resources, leading to weak animal health. They can cause up to 15% of economic losses in grassland-based farming systems as they lead to weight loss, anaemia, diarrhoea and can cause animal death in the most severe cases (Mavrot, Hertzberg, and Torgerson 2015).

The efficacy of anthelmintic[65] drugs is being threatened by current practices for controlling nematode infestations (Rose et al. 2015). Anthelmintics are mainly used on the entire flock, in a preventive way and without consideration of the health status of the animal. This favours the emergence of resistant nematodes that leads to lower to null efficacy of treatments (Sargison et al. 2007). In other words, it means that farmers and farm animals would have no other option but suffering infestations and hoping

[65] also known as worm medicines.

animals will be able to survive and recover. In short, there is a tension between the autonomy of the farm through grazing, current anthelmintic use and animal health on the long term.

The perspective of an anthelmintic breakdown would be transformational, if not dramatic, for ruminant production. First, it would mean a transition towards indoors livestock farming systems, with few or very low access to grasslands. Grasslands will change to forests and the multiple ecosystem services associated to grassland-based products would disappear (e.g. cultural heritage, biodiversity conservation and water quality (Dumont et al. 2019); or providing essential fatty acids (Duru et al. 2017)) while reinforcing others (e.g. flood control (Ford et al. 2012)). Second, for the farms maintaining grazing, no efficient anthelmintic would require i) lower stocking rates to decrease infestation risks and ii) lower individual production level as the immune response to infestations requires energy and proteins. In either way, it would increase production costs and might lead to an economic crisis of the industry. Even if the consequences on consumption are uncertain, given that consumers are used to low price food products, it could be assumed that consumers would not be flexible enough to compensate costs by buying at higher price. Overall, it could compromise entire zones where agriculture and territorial vitality depend on grazing (e.g. pastoral areas, (López-Santiago et al. 2014)). In this context where livestock production is trapped in the dead-end of relying exclusively on treatments to ensure animals' health, developing new livestock systems with integrated health management practices is crucial.

In this article, we look at the innovation potential of livestock industries regarding integrated health management through a preliminary network analysis. We explore the diversity of patterns of one-to-one information and knowledge exchange among 535 dairy sheep farmers, and between farmers and non-farmer stakeholders around the theme of parasitism control in the Pyrénées-Atlantiques (France). It enables us to illustrate how farmers' practices embed in sociotechnical systems, and identify the kinds of farmers' social environment involved in lock-in situations or in transitions towards agroecological practices.

Material and methods

Case study

The study covered the area of Pyrenées-Altantiques, in the South Western France, which ranks first in the country in number of dairy sheep farmers and second in sheep milk volumes (Agreste 2010). It covers 7,645 km² with mountains, hillsides and plains, and a coast to the Atlantic Ocean. Elevation goes from see level to 2900m, with summer pasture going up to 2700m. The climate is temperate oceanic, without dry season and with warm summers (rainfall between 1000 and 1700 mm/year, average minimal temperature: 8°C). Such climate is highly favorable to continuous grass growth, either in summer or in winter. Similarly, it is highly favorable to gastrointestinal nematodes infestations (nematode larva developing best at 20-30°C, in wet conditions, (O'Connor, Walkden-brown, and Kahn 2006)).

The main dairy sheep farming system in the area is a diversified livestock system with both dairy sheep and meat beef (70%), dairy cows (8%) or meat sheep (1%) (SRISET 2014). The average flock size is 224 ewes, and half of the farms have between 150 and 300 ewes.

The threat of a generalized resistance to any anthelmintic is a great concern among the local industry (CDEO 2017; GIS id64 2006). Resistances to one class of anthelmintic, benzimidazoles, have already been reported in most of local farms (Geurden et al. 2014) and other resistances are now reported for the other classes (Cazajous et al. 2018). On the top of that, dairy sheep farming is highly exposed to resistance risks because only few products are compatible with lactation: farmers keep using the same molecule from one year to the other, which increase the probability of resistance.

Key local stakeholders: sheep farmers and private veterinarians

Sheep farmers are key players in preventing the emergence of new resistance hotspots since the risk of resistance can be mitigated through both livestock management practices (grazing management, batches composition, diet, animal density) and animal health management practices (prevention, diagnosis and treatment of diseases). In the study area, numbers of sheep farmers are aware of the resistance issue. Still, most do not have any idea of how to adapt their practices for preventing it. This comes from two main points. First, resistance has been recognized as a concern by some local producers and private veterinarians only few years ago, and not every local producer or veterinarian are aware of it. Second, their is no ready for use protocol: managing parasitism is highly complex, solutions should be mixed and adapted to each farm, and some promising practices are still at a research stage (e.g. tanins, grazing management...). On the top of that, parasitism managment means dealing with tradeoffs between controlling infestations, avoiding resistance, and limiting the impact of anthelmintic drugs on the environment.

Although veterinarians are not the only suppliers of anthelmintic drugs, they remain the official point of reference on this matter. For example, they are the only ones legally able to diagnose and prescribe veterinary drugs. This explains why several founders and research partners had the following remark when we presented our research to them: "I am sure their vet is their main adviser". In practice, farmers can be out of reach of veterinarian advice as they can pretty easily find anthelmitic drugs somewhere else (internet, farmacy...). In France, we expect the role of veterinarians to be reinforced with the 2019-2020 campaing of mandatory health inspection visits, which focused on anthelmintic use and resistance risk. A transition to an integrated use of anthelmintics could reshape the relationship between veterinarian and farmers, as well as the economic model of private veterinary operations. For example, lower sales of anthelmitics might be compensated with increased advinsing prestations.

Survey development

The survey was designed by researchers in collaboration with local extension services : breeders' association staff including extension service agents and a veterinarian (CDEO Coop). It aimed at drawing up the diversity of health management practices and being able to test whether it could be correlated to farming systems, demographic information or farmers' social networks. The questionnaire has about 100 close-ended questions. The questionnaire is organized as follow: socio-demographic characteristics, farm structure and organization, livestock characteristics, dairy sheep management, dairy sheep health management, and farmer's social environment.

The survey was tested through two consecutive trials. Six people (two researchers, three extension agents and the veterinarian) did the first trial: we surveyed 10 farmers in real conditions and changed the survey according to farmers' feedback and our own suggestions. The 36 local technicians did the second trial: they tested themselves the second version of the survey in dedicated workshops. We changed the survey according to technicians' feedback and this was the final version of the survey.

Participants

The sample consisted in 536 dairy sheep farmers in Pyrénées-Altantiques who use or had used animal insemination. Most of them (97%) already had relationship with the local breeders' association either adhering to their technical performance monitoring and advising service or participating in their genetic animal selection scheme (providing rams or using semen). The association is the only structure providing these services to dairy sheep farmers in Pyrénées-Altantiques.

It was composed of 83% of men and the average age in the sample was 43 (from 19 to 70). Almost all participants were professional farmers (99%). The majority adheres to the technical performance monitoring and advising service (75%) and the average ratio of artificial inseminations is 40% per farm. In the sample, farms have 43 ha (sd=20) and 346 ewes (sd=157) in average, are mixed-systems (80%)

mostly combining dairy sheep and meat beef productions. Pasture area is 36 ha in average (sd=15), and half of the farms use summer pastures.

Survey administration

Data was collected by 36 advisers of the local breeders' association from February to April 2019 from 536 dairy sheep farmers (17% female, 83% male), representing 27% of the industry (Agreste, 2018). Interviews took between 45 minutes and 2 hours.

In addition to pre-testing the questionnaire, all advisers participated to a training workshop prior to going interviewing farmers. The training workshop aimed at i) presenting study rationale, goals and methodological choices, ii) providing face-to-face survey techniques adapted to the context of the study and iii) explaining questions meaning when needed. At any time of the study, advisers could ask assistance from a hotline. Depending on their preferences, advisors either typed data directly into LimeSurvey (version 2.50+) or filled out a paper copy of the questionnaire and then reported data into LimeSurvey interface.

Network analysis

Statistical analyses were carried out using R 3.5.3. Results were considered significant when the p-value was lower than 5%.

Network characterisation

We analysed one-to-one information and knowledge exchange regarding parasitism control. The data was collected with the question "Over the last two years, have you discussed with someone about some of your choices regarding parasitism management? If yes, please give their name".

We transformed answers into connection attributes (who is contacted, how many people are contacted, who contact, etc…). We tested correlations between network data and characteristics of the farms, farming practices and health management practices with chi2 test when the variable was qualitative and linear regression when it was quantitative. These correlation tests were carried out on two types of variables:

raw variables (e.g. size of the farm, number of ewes, number of treatment).

two composite variables, "farming system" and "nematode control cluster".

The farming system variable results from a hierachical clustering on the following five variables: main production on the farm, number of ewes, stocking rate, label for geographical indication (Yes/No), on-farm chees production (Y/N). The farming system diversity in our sample gives three typical farming systems: "Higher herd size without summer pastures", "Specialized farm and smaller herd size", "intermediate herd size with summer pastures". Similarly, the variable "nematode control cluster" results from a hierarchical clustering on the following variable: number of treatments (>2 or <2), selective treatment (yes or no), dose selection strategy (recommended or not) and practices against nematode infestations (recommended or not). These four categorical variable have been selected because they refer to nematode control practices that can generate resistance to anthelmintics.The clustering gives 4 clusters of nematode control management style. Clustering analysis were performed using the package FactorMineR (Lê, Josse, and Husson 2008).

Further network analysis was not relevant considering the low number of connections (the median number of connections per farmer is 1 and 25% of the sample were not involved in any discussion about parasitism (136 farmers)).

Results

Parasitism management: a non-subject for a third of the sample

Around a third of farmers interviewed declared not having discussed parasitism with anyone; we call them "autonomous farmers" in the rest of the article. In other words, 68% of farmers declared having discussed parasitism management with someone over the last two years. This was not correlated with nematode control clusters, nor with farming systems.

Farmers discussed with veterinarians, other farmers, advisers and random people (ranked from the most consulted category to the least). Among farmers who cited someone, 80% discussed with a veterinarian (resp 48, 36 and 12% with "other farmers", "advisers" and "random people"). The number of persons cited goes from 0 to 10, with a mean at 1,6 and a median at 1 person. This number did not correlate with nematode control clusters or farming systems.

Farmers' referents and trusted persons on the topic of nematode control

An underwhelming presence of veterinarians

Veterinarians are the first category to be cited as **contact person** on parasitism control (cited by 288 farmers). Veterinarians (either private or state) were also the first most "trusted" person regarding parasitism control, and were cited by 86% of the sample. This was not correlated with nematode control clusters, nor with farming systems.

However, around half of farmers (46%) did not discussed parasitism with any veterinarian, even if 97% of farmers surveyed bought anthelmintic to veterinarians. Most of them (175) fall into the category "autonomous farmer" presented above (in section 1 of results). Still, the others (73 farmers) discussed with someone but not with a veterinarian (more details in Figure 29). In other words, when farmers had talked to someone about parasitism, 20% of them did not exchanged with any veterinarian.

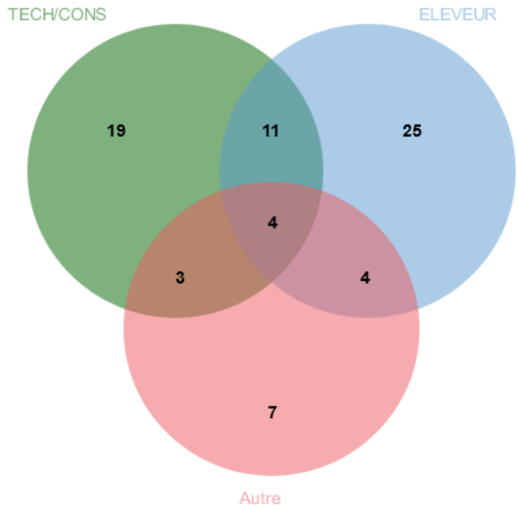

Figure 29 : Venn diagram of the persons cited (farmers, advisers or random person) by the farmers who did not discussed with veterinarians (n=73).

As this situation can be rooted within both farmers' and veterinarians' attitudes, we wondered if some veterinarians were more prone to discuss parasitism control with farmers than others. Some variability exists within veterinarians, with some talking about parasitism control to all of their clients and other talking with none of them (see **Erro! A origem da referência não foi encontrada.**). In average, it seems t hat each veterinarian discussed parasitism with half of the farmers they advise (47%, sd= 33). Such information should be interpreted with caution as our results are based on farmers' declarations only, and we have not surveyed veterinarians. A farmer might not consider as an "advice" or "discussion" when a veterinarian providing and selling an anthelmintic. On the other hand, a veterinarian might see it as an advice and discussion since it would imply advising a molecule, and a dose adapted to the farm and animals considered.

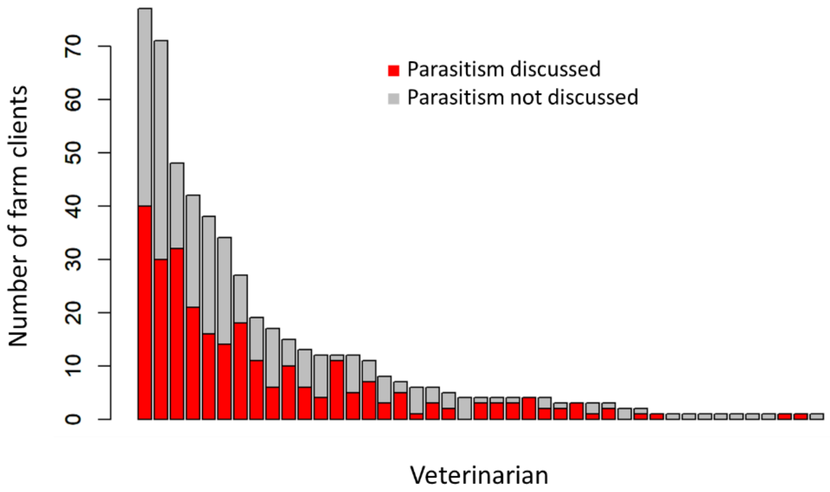

Figure 30: Number of farmers who discussed (red) and did not discussed (grey) parasitism control with their veterinarian, for each veterinarian cited.

Those who discussed with at least a veterinarian, i.e. the other half of the sample, mostly cited one veterinarian (in 88% of cases), or two (8% of cases). The number of veterinarian cited did not correlate to the variable "nematode control cluster". However, in three of the five clusters of nematode control, a veterinarian was over-cited in each specific cluster.

Farmers: the second referent in parasitism control

Farmers were the third most "**trusted" person** regarding parasitism control, and were cited by 27% of the sample.

Farmers are the second most cited category after veterinarians as **contact person** on parasitism control (cited by 173 farmers). They were mostly cited with one or more veterinarians (129 farmers, more details in Figure 31), which scored higher than the "veterinarian only" response (96 farmers). In total, 146 farmers were cited namely, and farmer names were not specified in 51 answers. Farmers were cited from 0 to 6 times, and 1.6 times in average when they are cited. Twenty farmers names were cited more than twice. They were not over-represented in any nematode control cluster, or any farming system.

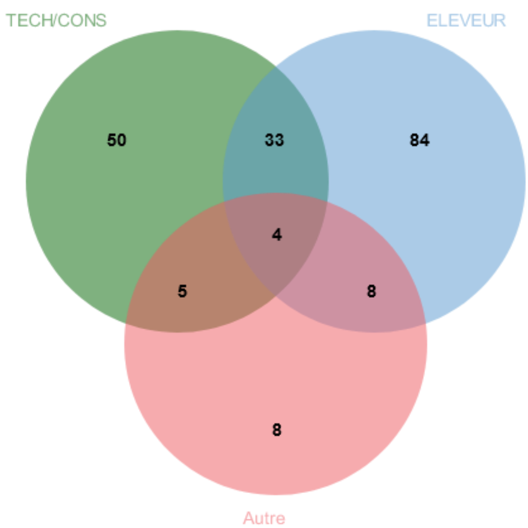

Figure 31: Venn diagram of the persons cited (farmers, advisers or random person) by the farmers who discussed with one or more veterinarians (n=288, including 96 farmers who cited only one or more veterinarians – bot represented).

We focus now on the farmers who declared having discussed with someone about parasitism.

They discussed with 0 to 8 other farmers, with an average of 0.9 farmers cited by answer (zero excluded). The 48% discussed with one or more farmers.

Advisers: from a potential support for veterinarians to substitutes

Advisers ranked second as **trusted person** regarding parasitism control, and were cited by 52% of the sample.

They were the third most cited category as **contact person** on parasitism control (cited by 129 farmers). They were mostly cited with one or more veterinarians (92 farmers). Advisers were cited from 0 to 5 times, and 1.2 times in average when they are cited. Ten adviser were cited more than twice, with an outstanding adviser cited by 17 farmers. Advisers were mostly cited "alone" (with no other adviser cited). Citing or not an adviser correlated with the farming system: the specialized farms with small herds tended to not cite advisers.

Some farmers (37, i.e. 10% of the farmers who cited someone) discussed with an advisers and no veterinarian.

Discussion and conclusion

In our study, a large proportion of the farmers surveyed had not discussed parasitism with anyone. This will be a major barrier to transitions towards a decreased use of anthelmintic. It would hinder the first stage of a change towards an alternative practice ("awareness of the problem or opportunity" (Pannell et al. 2006)) to happen: if farmers do not talk about nematode control practices they reduce their opportunities to hear about alternative practices. This is even truer in our sample where human referents (veterinarians, advisers and farmers) were more trusted than specialized periodicals to inform on nematode control. In an extension perspective, we should explore the reasons for this result to design a program that would be adapted to this specific population. Among others, parasitism control could not an issue for them, or they perceive they are not able to change practice (for example because "it is the veterinarian' role"). They might have other priorities, or be not aware of resistance risk and their expected impacts. Finally, it could be related to farmers' ideals of autonomy (Stock and Forney 2014) and in particular the way farmers perceive the role of veterinarians in health management. These "autonomous" french sheep farmers might consider, as UK sheep farmers in 2013, that they are the only ones able to manage their flock and no other people would be able to provide them with any relevant advice (Kaler and Green 2013).

In the same vein, it was surprising to see that not every farmer we surveyed cited veterinarians. It reveals a limited reach of veterinarian advice on the matter of parasitism control. Further research is needed to better understand this situation. Our thoughts is that parasitism control might has become a routine for both veterinarian and farmers so no advise is repeated from one year to the other, even if molecule and dose should be adapted each time a drug is sold.

The study showed that trusted persons were not exactly the same one as referent persons. In other words, farmers who discussed about parasitism were not necessarily seeking an advice. Surveyed farmers sought both information and advice on parasitism control. This shows that supporting farmers in their changes in nematode control practices should involve wider actors than veterinarians and involve other postures than prescribing solutions. It calls for a transformation of knowledge circulation in the agricultural sector where knowledge is not only hold by experts (veterinarians, advisers…) but where knowledge circulate among any person belonging to a community of practices and interest, including farmers.

Most often, farmers consulted more than one referent. Each additional referent represents a new opportunity to talk about practices; however the associated risk is to generate confusion and inaction if discourses diverge from one referent to the other. Coordination between actors it thus key in reducing anthelmintic use. Participatory processes can be a tool to facilitate such coordination between stakeholders and even trigger stakeholders' interest in, and motivation to reducing resistance risk on the territory.

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TRANSITION TOWARDS SUSTAINABLE FOOD SYSTEMS: A FOCUS ON WORKPLACES, WORKERS AND FOOD PRACTICES AT WORK

Chloé Le Bail[a], Marianne Cerf[b]

[a] AgroParisTech, UMR SayFood, France
[b] INRAE UMR 1326 LISIS, France

Abstract

To reach sustainability, it is now well recognized that food systems need significant innovation and transformation of the existing corporate food regime. Many scholars analyze top-down innovations (innovations thought and promoted by some actors, e.g. engineers, for the benefit of other actors, e.g. farmers) and bottom-up initiatives (innovations developed by some actors for their own benefit). They investigate the complex dynamics of coupled innovations in technologies (e.g., recycling technologies, agronomic practices) and in non-technological areas (e.g., cooperation between food system actors, different organizational arrangements, consumption practices). However, few studies have precisely explored how work, workers and workplaces are impacted by these transitions; and how work, workers and workplaces may be the catalysis of such transformations. The present paper proposes a methodological approach to explore how both bottom-up and top-down initiatives transform work activities, as well as how these changes are included in new sociotechnical arrangements. We use the conceptual framework of the design of sociotechnical systems in ergonomics. The research focus on workplaces (e.g., companies) transition towards sustainable food practices and aims to explore work and workers at different scales: employees-consumers, producers, cooks, decision-makers, etc. The methodological model combines: (i) the evaluation of work activities, from the production, to the transformation, distribution and consumption of food; and (ii) the anticipation of new sociotechnical arrangements which take into account social (skills, knowledge), organizational (rules, procedures), practical (economic, technical such as physical spaces) and ideological (values) issues. Iterations between the two phases aim to contribute to both the development of work activities and the durability of the local food system.

1. Introduction

To reach sustainability, it is now well recognized that food systems need significant innovation and transformation of the existing corporate food regime (Meynard et al., 2017; Elzen et al., 2017). Sustainable food system is defined as a set of practices, from the production to the consumption of food products, economically viable, socially sustainable and ecologically responsible (Gaitán-Cremaschi et al., 2019). This is not only about organic food. It relates to the quality of the food, the number of intermediaries and the geographic proximity as well (Renting et al., 2003; Ostrom et al., 2017).

Over the last two decades, the field of *Sustainability Transitions Studies* has explored processes of innovation in agrifood systems (Elzen et al., 2017). Many scholars analyze top-down innovations (innovations thought and promoted by some actors, e.g. engineers, for the benefit of other actors, e.g. farmers) and bottom-up initiatives (innovations developed by some actors for their own benefit). They investigate the complex dynamics of coupled innovations in technologies (e.g. recycling technologies, agronomic practices) and in non-technological areas (e.g. cooperation between food system actors, different organizational arrangements, consumption practices) in activities of growing, processing, distributing, consuming and disposing of foods (Marsden et al., 2018). They identify local food systems as social innovations which encourage fair prices, solidarity, democracy and participatory processes between different actors, especially farmers and consumers (Chiffoleau and Loconto, 2018). Here, Social Innovation refers to a set of "innovative activities and services that are motivated by the goal of meeting a social need" (Mulgan et al., 2007, p.8). This generates new forms of coordination and collaboration between people and promotes community values such as equity and mutual aid (Harrisson and Vézina, 2006). Finally, there is a stream of research within Innovation Studies that focuses on the governance of systems transitions and transformations (Borrás and Edler, 2014; Turnheim and Nykvist, 2019).

Sectors concerned by sustainability transitions can be conceptualized as *sociotechnical systems* (Markard et al., 2012; Geels, 2004; Weber, 2003). In the field of Transition Studies, such systems consist of *"(networks of) actors (individuals, firms, and other organizations, collective actors) and institutions (societal and technical norms, regulations, standards of good practice), as well as material artifacts and knowledge"* (Markard et al., 2012, p.956). The systemic approach highlights the fact that the various elements are interrelated and dependent on each other (Hughes, 1987). A sociotechnical transition concerns both the elements of the system and the dynamics between these elements. This involves changes along different dimensions such as material, organizational, political, economic and cultural; and leads to the emergence of new products, services, business models and organizations (Geels and Schot, 2010). Furthermore, sociotechnical transitions differ from technological transitions because they interest changes in users' practices and institutional structures. Sociotechnical transitions impact domains such as trade, housing, working and policymaking (Markard et al., 2012).

Current studies on transition in food systems focus on what innovation in food systems is, how it emerges, how to support it and how to assess it. They analyze economical, technological, political, institutional and social issues of transition towards sustainability in food systems. However, few studies have precisely exploring how work, workers and workplaces are impacted by these transitions; and how work, workers and workplaces may be the catalysis of such transformations. Firstly, few studies have investigated "what is eating sustainable food at work", including how eating at work is constrained by work dimensions, the work environment and the logics that are all vital to the development of the company such as finances, marketing, human resources, quality and sustainability. Indeed, studies on sustainable out-of-home eating mainly focus on territorial collectivities and public catering (e.g. school canteens, seniors' residences and hospitals). Secondly, few studies have explored how both bottom-up and top-down initiatives transform work activities, neither how these changes are included in new sociotechnical arrangements.

2. Research objectives

This paper focuses on workplaces (public and private sectors) transition towards sustainable food practices and aims to explore work and workers at different scales: employees-consumers, workers involved in the development of the local food system, cooks, managers, decision-makers and staff representatives. The main objective is to propose a research methodology which helps bottom-up and top-down initiatives to meet each other, and which considers the work of the diverse actors. We use the conceptual framework of the design of sociotechnical systems in ergonomics. We assume that transition in workplaces is a "design" process, i.e. a continuous process, collaborative and situated which involves solving an ill-structured "problem" (Simon, 1973). This means it is not possible to predict the final state of the system (i.e. the "new" functioning of the workplace "after" the transition, the "new" arrangements between actors). A lot of states may be reached or considered, due to desirable futures more or less defined by the actors; and due to a vision of the "future" system more or less shared between them.

Such design process results in open discussions and negotiation between the various stakeholders, considering the indeterminate intertwining of the technical (technologies, artefacts), social (work organization) and ideological (beliefs, values) aspects of transition towards more sustainable food practices. Our methodology seeks to respond to the following questions: (i) What are the initiatives of both employees and workplaces towards sustainable food practices at work? How these two types of initiatives interact? (ii) How these initiatives transform the organization of the work in the local food system? Do these transformations lead to the development of workers (i.e. the development of skills and knowledge on their work situation and on the whole food system)?

At first, we explore the literature on sustainable food practices in workplaces and in everyday life, and we highlight a lack of consideration of the relationships between these practices and work activities. Then, we propose both a theoretical framework and a methodological model to focus on work and workers during sustainable transition. We finally discuss the contribution of our methodological proposal to enhance workplaces transition towards sustainable food practices and to support the development of local food systems.

3. Sustainable food practices in workplaces

Food practices in workplaces may be considered with two aspects: (i) providing sustainable food for employees, generally through canteens and cafeterias within companies (workplace catering); (ii) the daily lunch strategies of employees (e.g. canteen, ready-meal, food cooked at home, grocery shopping, food-truck, sandwich bar, go home, etc.). Both aspects do not just concern food products. They are influenced by the environment as well (Dagevos, 2005). Food consumption involves structural, social, cultural and economic contexts such as organization of the daily life, physical infrastructures of consumption, routines, norms and politics, groups and individuals' values (Sargant, 2014; Di Giulio et al., 2014; Spaargaren et al., 2013). Food choice is also influenced by personal factors such as taste, money and time (Jabs and Devine, 2006; Blanck et al., 2009).

3.1. Sustainable food practices in workplace canteens

Research on sustainable food practices in the sector of workplace catering mainly focuses on how such practices boosts the sustainable food economy; how it improves consumer's access to healthy and sustainable food; how functions the sustainable canteen food provisioning; and how practices of end-users are taken into account and satisfied or not.

For example, the study of Mikkelsen et al. (2005) compares the nutritional quality of the menu offered to customers in "green" and "non-green" workplace canteens. Results show that green canteens have more healthy options in their menus than non-green ones, due to the use of seasonal vegetables more extensively. This implies that caterers change their practices and procedures to match the current supply of organic products.

The study of Goggins (2016; 2018) focuses on the role of large organizations (e.g. hospitals, schools, prisons, workplaces which employ over 250 people) in the emergence of sustainable food systems. The study of Sargant (2014) analyses which factors influence the success of sustainable food provisioning, including the working relationship between caterer and contract-lender, the organization and infrastructures of kitchens, and the canteen food culture (habits, norms and expectations). These two studies highlight that the development of relationships between canteens and rural communities (local producers) requires a significant change of food provisioning practices. It implies the skills of diverse food professionals and it changes the work of actors involved. Catering managers, which do not have knowledge on sustainable procurement (e.g. food seasonality), undertake regular tender training to cope with the "new" food procurement. Local producers are not competent to deal with tender documents. Cooks do not have culinary skills and adequate materials to cook the 'new' food products (i.e. generally less transformed). Furthermore, these two studies highlight the role play by NGOs (Non-governmental organizations) to educate people about food and to promote healthy sustainable eating. Companies forge strategic relationships with these actors to increase their sustainability performance (Goggins, 2016).

Finally, the study of Spaargaren et al. (2013) highlights that employees-consumers of workplace canteens have "robust" practices in terms of time and price allowed for lunch, place preferred to sit, expected food to eat, opinions on food labelling, etc. These particular practices shape the system of provision of food which tries to respect these practices and the dynamics between them. Transition must consider the existing activities and their dynamics.

3.2. Daily lunch strategies of employees and sustainable food consumption in everyday life

Sustainable food practices at work concerns how employees attempt to eat "green" during working time as well. Research on daily lunch strategies of employees mainly focus on how and why employees choose the canteen or other food service provision (commercial catering). Several factors determine food choices of employees (Blanck et al., 2009; Mathé and Francou, 2014; Lhuissier et al., 2018). The most cited in previous studies are: ratio price-quality (i.e. cost and taste/healthfulness); proximity and convenience (related to the time allowed for lunch); social factors such as eating with friends, colleagues or family (e.g. going back home to eat with the children); and the diversity of the food offer in the area of the work (the presence of a canteen within the company, diverse food services).

Research on sustainable food consumption does not focus on consumption during work, but rather concerns how consumers purchase sustainable products in their daily life. Sustainable food consumption can be defined as the way of consuming food to minimize the effect on the environment and to contribute to the local economy by making socially responsible choices (Sargant, 2014; Azzura et al., 2019). Again, previous studies indicate that several factors underly sustainable purchasing behavior (Squires et al., 2001; Pino et al., 2012; Verain et al., 2012; Hemmerling et al., 2015; Azzura et al., 2019): consumer involvement in sustainable products; sustainability knowledge and concerns (e.g. animal welfare, support to fair prices for farmers); personal values; socio-demographics factors (age, gender); distrust on conventional food products (perceived as less healthy and safe); and lifestyle variables. However, these studies generally consider that sustainable food consumption is only the result of people rationality, motivation, needs and preferences (Sargant, 2014).

Other studies based on practice theory – which analyses the social and physical (i.e. environment, spaces, infrastructures) dependencies of consumption – acknowledge the contextual and collective nature of food consumption (Shove and Pantzar, 2005; Jackson et al. 2007; Spaargaren and Oosterveer, 2010). The context of consumption is seen as both constraining and enabling, i.e. as influencing negatively or positively our food habits. This depends on the sociotechnical system in which the consumption occurs and that precondition certain modes of provisioning, access and use (Spaargaren and Oosterveer, 2010). For example, the study of Sargant (2014) shows that consumers choose alternative products which do not involve substantial changes in cooking, eating and shopping practices. That means they choose products which do not change their everyday food practices, notably in terms of skills, time and money. Sargant (2014) highlights the importance "to investigate food consumption in relation to practices of food consumption and their contexts" (p. 87). Again, the study highlights that NGOs constitutes important sources of information for consumers.

4. What about work and workers?

The literature on sustainable food consumption, both in workplace canteens and everyday life, shows that transition towards sustainable practices concerns activities of all actors involved in the sociotechnical system. More precisely, such transition involves technical (equipment, physical spaces), social (skills, knowledge), organizational (rules, procedures) and ideological (norms, values) issues.

However, work is an activity which is impacted by sustainable food transition and not really investigated. On the one hand, previous studies acknowledge changes in the work of workers involved in the food system (cooks, catering-managers, producers, deliverers). But these studies do not investigate precisely the transformations of work activities, neither how to support these transformations. How workers acquire skills? Are changes in food practices safe for workers? Do these changes correspond to the needs, abilities, expectations and values of people? Do these changes optimize human well-being at work? Shortly said, do work transformations respect the social dimensions of sustainable development? On the other hand, previous studies on sustainable food consumption in everyday life do not pay attention to consumption in working contexts. How consumers, in a working context, buy and eat sustainable food? What are their expectations? What are their food practices? Is the work environment appropriate for sustainable food consumption?

Figure 1 illustrates our vision of the system of work activities related to sustainable food provision and consumption at workplace. The notion of *workplace* is used as *set of places where people are during working time*. This is the spatial environment where the work occurs. It includes companies and institutions (public and private sectors). But we consider *places of work* as larger than organizations and companies, to include other places where people do their work (e.g. meetings outside the company, in another company or in a restaurant, teleworking, etc.). With such a perspective, it is possible to consider a lot of ways of consuming sustainable food. And it is possible to investigate the frontier between food places and workplace (i.e. working and eating at the same time, such as during a business lunch).

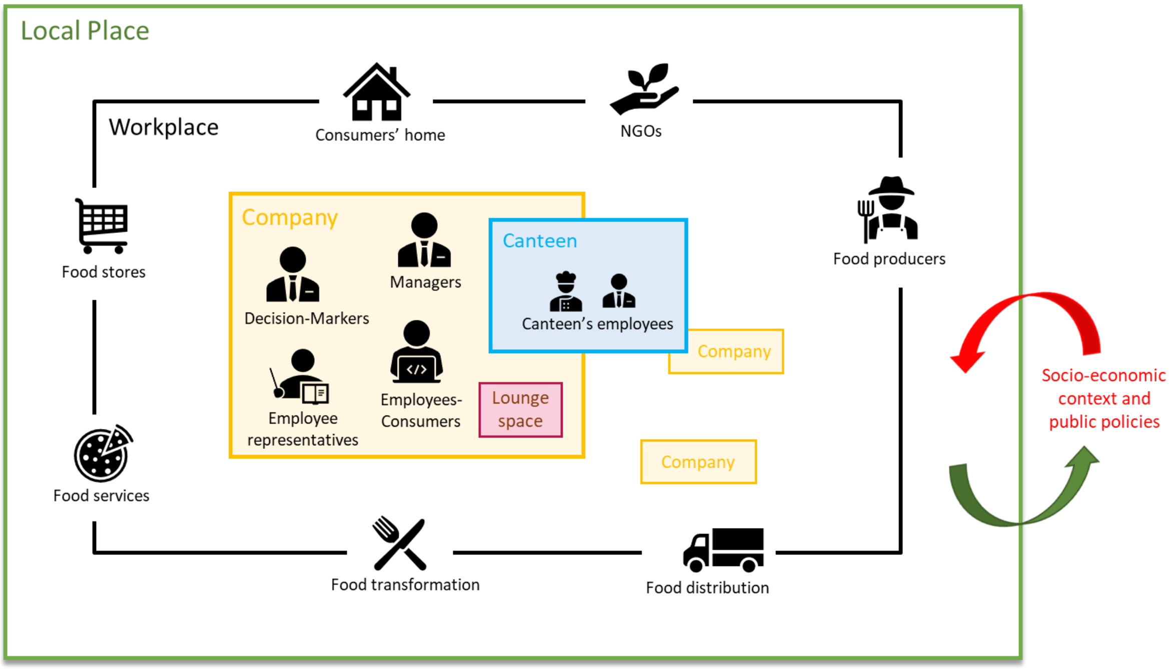

Figure 1. The system of work activities related to sustainable food consumption in workplace.

We see workplace as part of a local food system which involves a number of companies (or institutions). Local place comprises food producers, NGOs, food transformation and food distribution. In addition, local place includes places where employees-consumers eat during working time (their home or friends/family's home, food stores, food services such as food-truck, fast-food, etc.). Workplace comprises diverse companies which provide or not a canteen for their employees. Canteens are shared or not between various companies. Within workplace, employees have different opportunities to eat sustainable food such as the canteen, other food services, staff lounge spaces (i.e. bringing food at the office) and food stores. These opportunities depend on the characteristics of the workplace (e.g. urbanized area, industrial zone, commercial zone) and the specificities of the work (e.g. work schedule). Decision-makers, managers and employee representatives (e.g. syndicates, occupational medicine, professional associations) play a role concerning the organization of the work and the implementation of a canteen or a cafeteria within the company; and they are food consumers too. Within canteens, there are work activities such as food transformation and food preparation; and there are employees such as cooks and catering managers. Every cited actor (and their work activities) interact with each other. Furthermore, local food system influences – and, in turn is influenced by – publics policies and socio-economic context.

In the next section, we propose a methodological approach to investigate work and workers, considering the different scales of work activities within the local food system.

5. Methodological proposal: sustainable transition as design process

Our methodology combines: (i) a data collection among employees and companies who take initiatives to develop food practices at work which claim to be more in line with sustainability issues; (ii) an involvement in some associations (NGOs) which purpose is to support companies in developing sustainable food practices; (iii) the design of projective scenarios of new sociotechnical arrangements within the local food system. Our methodological proposal is based on the conceptual framework of design of sustainable sociotechnical systems in ergonomics.

5.1. Conceptual framework: design of sustainable sociotechnical systems in ergonomics

Ergonomics is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize both human wellbeing and overall system performance (Definition from the International Ergonomics Association). Ergonomic design concerns products, services and work organizations. Design projects are organized in two major phases: 1) identifying the determinants of human activity to specify design solutions; 2) anticipating activity changes that are inherent to the implementation of these new solutions. The first phase involves quantitative and qualitative methods of data collection such as survey, interviews and field observations. The second phase involves projective methods (e.g. simulation, prototypes such as drawings, mock-ups and storyboards) to adjust and enrich design proposals (Béguin and Cerf, 2004). Ergonomics concerns work as well as other application domains (e.g. transport, energy, etc.).

At its early beginnings, ergonomics has set its goal as fitting jobs and workstations (work positions) to the human. Then, the scope of ergonomics has expanded to the optimization of work systems in companies including their organizational structures, policies and processes (e.g. team management, design of working times, cooperative work, prescription of rules). Work situations involve both technical (e.g. work tools, objects, technologies, physical spaces) and social (e.g. individuals' motivations, relations between workers) determinants within work organization (rules and procedures). In that respect, the notion of *sociotechnical system* in ergonomics refers to the dynamics between the technical system and the social system within work organizations.

These recent years, organizational (sociotechnical) design is situated in the field of constructive ergonomics (Falzon, 2014). It aims at supporting the development of individuals, collectives and organizations. The notion of development refers to the construction of know-how, knowledge and skills regarding the "future" work organization along with health and performance issues. The methodological approach of such design projects is based on the integration of multiple actors with different visions. This refers to a participatory design approach where workers negotiate with other stakeholders (mainly managers, prescribers of the work) organizational solutions (Damodoran 1996). Participatory design suggests moments of meetings, discussions and deliberations (i.e. democratic decision-making). Organizational design is viewed as a collaborative design process of rule-making, which requires collaboration and management of points of view (Barcellini et al., 2014). Constructive ergonomics aims at designing enabling organization for the development of both individuals and collectives. "Enabling" or "empowering" is used in reference to Sen's work and the capabilities approach (Sen, 2009). Capabilities are alternative combinations of functioning that are feasible for a person to achieve (e.g., for mobility, for participating to the politic life, for feeding, etc.). Enabling systems increase capabilities if the organization provides resources to transform social and technical potentials into effective possibilities. However, this field of ergonomics has two limits to understand and to support both sustainability transition and social innovation (Le Bail, 2018). Firstly, it does not take into account ideology (system of values) within the design process of work situations. Secondly, projects are intra-organizational and initiated by a request of a company which encounter difficulties such as absenteeism, dissatisfaction, lower productivity, workers with health problems, etc. Constructive ergonomics is mostly limited to small-scale sociotechnical systems (i.e., limited to a few work/use situations, and limited to one organization). It does not interest projects at regional level.

Design of innovations is situated in the field of prospective ergonomics (Robert and Brangier, 2012). Innovation is used as "undefined future" and prospective ergonomics means searching for novelties and alternatives in design. Within projects of innovation, ergonomics focuses on artefacts to create as well as needs and activities to define. This is based on prospective, which consists in looking forward in time through the analysis of several factors such as economic, social, technological, political or environmental (Godet and Roubelat, 1996). The scope is much larger than the scope of transformation (i.e. scope generally used to apprehended organizational design). Prospective ergonomics attempts to responds to the importance for companies to innovate and remain competitive in the global economy. The approach encourages working sessions with end-users and experts of the domain, supported by creative methods to generate and assess the maximum of design solutions. For example, these methods and tools are Brainstorming (Osborn, 1953) and Personas as archetypical representations of end-users (Pruitt and Grudin, 2003). Prospective use projective methods and tools as well. They help the diverse stakeholders to imagine what the future system is. For example, these methods are scenario-based design (Carroll, 1995) and storyboards (Hart, 2008). Again, this field of ergonomics has limits to understand and to support both sustainability transition and social innovation (Le Bail, 2018). Prospective ergonomics mainly concerns products and technologies but do not interest new forms of organization in society.

Recent studies in ergonomics have investigated innovation and transition in local systems (Le Bail, 2018; Détienne et al., 2019). Based on the two previous fields, these studies consider this is a collaborative design process of new dynamics between social system, technical system and ideology (system of values) within local organization (coordination between actors, design of rules in local scale influenced by larger scales). In a sustainability context, transformations of work activities are socially and ideologically embedded, as far as stakeholders consider necessary to take into account the insertion and future position of the system in its societal and cultural environment. Values of sustainable development underlie the design of organizational solutions (i.e. coordination of work activities within the system) and practical solutions (e.g. technological, economical, etc.). This involves design methods which support discussion on both sociotechnical and ideological issues.

5.2. Methodology for sustainable transition in food systems which focuses on work, workers and workplaces

We propose a method with two phases, iterative and integrative (Figure 2). The iteration between the two phases is constructive, i.e. favourable to the development of work activities (construction of skills, know-how and knowledge); and to the development of the local food system in which the workplace evolves (continuation, durability, longevity). The two phases correspond to the two main phases in design projects: evaluating (analysing, understanding, identifying) and anticipating (transforming, innovating, designing). They help to study how transition affect work, workers and workplaces, and how in turn, work, workers and workplaces affect transition.

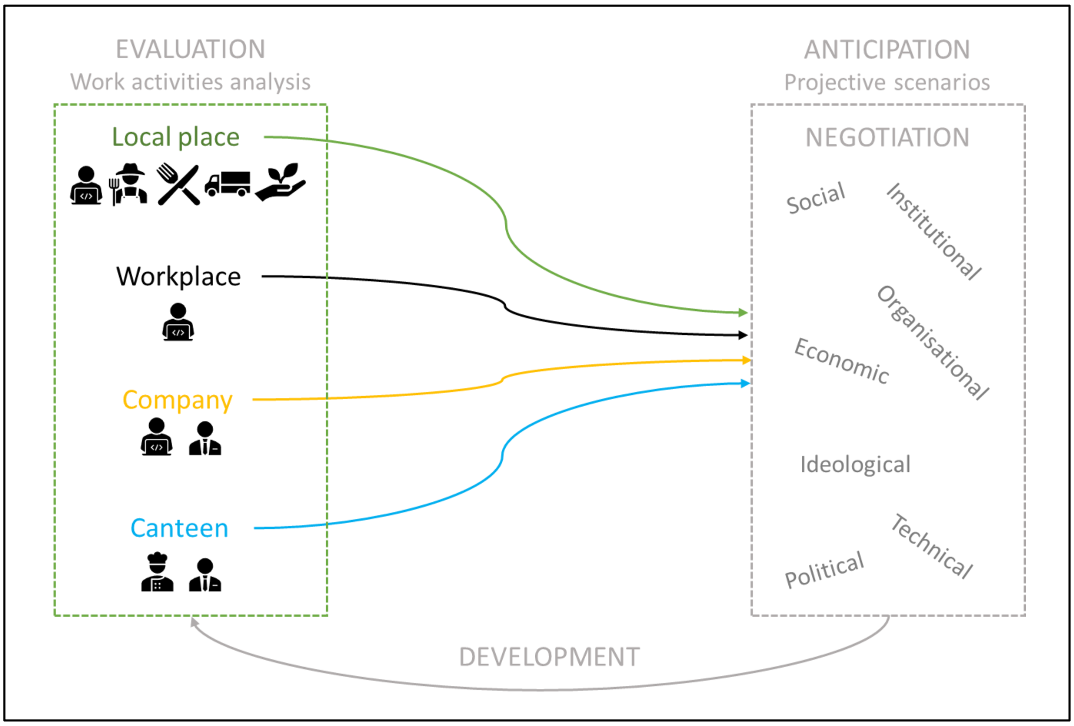

Figure 2. Illustration of the iterative process between phase 1 (evaluation) and phase 2 (anticipation).

5.2.1. Phase 1: Evaluation of the various work activities within the local food system

The first phase (Table 1) seeks to analyse the work of the diverse stakeholders of the local food system. This concerns activities of production, transformation and distribution of food, activities of NGOs supporting the development of the system, activities of employees as actors of the local place, the workplace and the company, and activities of canteens' employees (Figure 2).

The empirical material is both quantitative and qualitative (discourses, practices). The data collection comprised: (i) online surveys; (ii) interviews of employees concerning their food habits during work time (sustainable or not); (iii) interviews and observations of workers whose activities take place in more sustainable food production, transformation and provision; (iv) interviews of companies which have evolved or plan to change to sustainable food practices at work (via managers and decision-makers); and (v) interviews and observations of associations/NGOs, which help companies' transition towards sustainable food practices.

Table 1. Phase 1 (Evaluation).
Identifying internal factors (knowledge, motivation, values) and external resources (technical, organisational, environmental) related to sustainable food practices.
Identifying what are the determinants (e.g. social, organisational, economic) of work for the implementation of sustainable food practices.
Identifying effective possibilities for the implementation of sustainable food practices; and identifying which criteria facilitate or interfere with these possibilities.
Investigating innovative practices concerning sustainable food in workplaces, as well as innovative local food systems and innovative collective practices.

Such analyse is meant to identify the various activity systems according to their respective object and motive (e.g. which sustainable food practices do they claim) and to their respective coordination rules and the way this influence work transformation. It is not possible to analyse all the organization of the local food system. We seek to identify various modes of organization between the diverse stakeholders and analyse how these modes of organization are related to sustainability values. Then, we seek to identify how the various modes of organization may be articulated (which constraints and opportunities) in order to develop work and workers.

5.2.2. Phase 2: Anticipation of the new arrangements within the local food system

The second phase (Table 2) seeks to support the design of innovative solutions, based on constructive negotiation between diverse issues which are related to sustainable transition (e.g. social, ideological, political, institutional, technical, etc. See Figure 2). This concerns all stakeholders involved in the local food system. The negotiation between diverse constraints is made possible through the design of projective scenarios which imagine probable, desirable and acceptable futures.

The empirical data is qualitative (mental representations, opinions, practices). The data collection comprise: (i) focus groups and creative design workshops with all the diversity of stakeholders and with experts of the domain (e.g., associations/NGOSs which support companies' transition); (ii) language-based simulations (role-playing game, system mapping, storyboard...) with all stakeholders and with experts of the domain; (iii) feedbacks of stakeholders (interviews and observations).

Table 2. Phase 2 (Anticipation).
Creating conducive conditions for the expression of multiple point of views, needs, constraints and expectations concerning the implementation of sustainable food practices.

Creating conducive conditions for the development of knowledge about the future situation (i.e. negotiation, "debate spaces").
Designing scenarios of actions collaboratively.
Simulating the solutions.
Assessing the solutions collaboratively
Giving the opportunity to generate a lot of ideas, to create innovative solutions and to evaluate these solutions collaboratively.

6. Concluding discussion

Transition towards sustainable food systems cannot ignore the work transformations of actors involved at different scales, from production to transformation, distribution and consumption. In that respect, our paper presents a methodological approach to explore how work, workers and workplaces are impacted by the development of local food systems; and in turn, how they contribute to the development of the local food system. Our approach proposes iterations between work activities analysis (evaluation of the system) and projective scenarios (anticipation of new arrangements within the system).

Future research concerns the application of our methodological approach. We plan to explore the Saclay territory (Saclay plateau) located in the south of Paris. This is a peri-urban project territory which involves both urbanization and rurality issues, and which is favourable to the emergence of local food systems. Saclay is an open space close to a dense urban area and where prosperous agricultural activities remain, despite huge construction sites for the installation of both private companies and public infrastructure (like universities). Local stakeholders try to preserve agricultural and natural spaces to develop the well-being of people. Local initiatives (i.e. short food-supply chains) have emerged to help the connection between local consumption and local production (Tedesco et al., 2017). Through our data collection, we wish to identify individual and collective actions of employees-consumers as well as actions envisaged and/or implemented by companies, to understand how the work of all stakeholders involved in the local food system is impacted by the sustainable transition. Through our involvement in NGOs which advised companies on sustainable food practices we try to equip them to open discussions with the various stakeholders in order to take into account the technical, social and ideological aspects of work organizations in transition towards more sustainable food practices.

We expect to highlight that transition towards sustainable food systems is integrated in a working context which includes work, workers and workplaces. We expect to identify how work activities reshape the sociotechnical system, and in turn how work is influenced by new sociotechnical arrangements. Concerning our methodological model, we expect to offer for practitioners (including NGOs) who manage a process of change, tools and methods to identify and to anticipate the key components of the work involved in the transition. Another important contribution lies in the interest in systems of ideas and values (i.e., ideologies) on the levels of organisations, communities and society, which is not that much considered within design projects related to sustainability issues.

To finish, we hope to extend the scope of debate on Sustainability Transitions Studies and bring an ergonomics' point of view of how both technical and social processes are interrelated in society. Indeed, both sociotechnical system and sociotechnical transition do not have the same signification within the two fields of research. But they are conceptualized identically, i.e. as the articulations between technical and social determinants within (societal or work) organization. The analysis, at different scales, of sociotechnical dynamics related to transition towards sustainable food systems may enrich the understanding of such transition.

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THE CONSTRUCTION OF NETWORKS IN ITALIAN SOCIAL FARMING

Patrizia Borsotto, Carmela De Vivo, Marco Gaito, Antonio Papaleo, Gabriella Ricciardi, Michela Ascani, Giovanni Dara Guccione

[a] CREA – Research Centre for Agricultural Policies and Bioeconomy

Introduction

Multifunctionality in agriculture becomes a strategy to diversify business activities in response to the new demand for goods and services to the primary sector expressed by consumers since the end of the last century (Fabiani 2014; Aguglia et.al, 2009). The agricultural world - in a new "post-productivist" perspective, of multifunctional agriculture and of sustainable development of rural areas - discovers the new capacity of the farm to promote a wide range of services that complement the traditional function of producing food (Senni, 2010; Giarè et al. 2018).

Social farming (SF) is part of this framework, offering innovative services, enhancing and mobilizing local resources, strengthening networks of relationships and ensuring a new reputation and visibility for local actors (Senni, 2013). Social farming practices, widespread in Italy, are carried out by farms, agricultural cooperatives, social cooperatives, public companies, public and private health and social structures and find in Law 141/2015 "*Disposizioni in materia di agricoltura sociale"* the regulatory framework of reference.

One of the goals of Europe 2020 Strategy that aimed at promoting "a smart, sustainable and inclusive growth and at achieving high levels of employment, productivity and social cohesion" is the importance of social inclusion and the fight against poverty. The programming cycle of the European Structural and Investment Funds 2014-2020 gives an important opportunity for social farming development (Ascani and De Vivo, 2016).

Social farming represents an innovative solution for the cohesion of territories. It intervenes both on the need to meet new social requirements for protection and services to people in rural and peri-urban areas and on the possibility of encouraging the development of rural networks able to promote social entrepreneurship. SF promotes solidarity and professional integration in social enterprises and the social economy in general in order to facilitate employment for disadvantaged people.

Local and national networks have been set up in the areas concerned with the development of SF. They originate from the traditional rural self-help networks that were well established in rural areas before the modernisation of agriculture and the rise of the public welfare system. Some local networks have given rise to initial ways of formal recognition of social farming practices by those responsible for social and health policies. Recently, from an organisational point of view, interesting links have been established between the world of agriculture and social enterprise, which mediate skills and entrepreneurial networks with those of social cooperation, mobilising available resources in a new way to create economic and social value. It is a question of enhancing, alongside the formal networks of services, informal networks aimed at the formulation and provision of services by the farm. Social farming develops in this sense as a practice that integrates agricultural activities with other ones- social, welfare, educational, etc. - based on cooperation between different actors, sectors and areas (Foti et al., 2014; Lanfranchi et al., 2015; Scuderi et al., 2014; Steigen et al., 2016). In this light, SF includes public-private partnerships, community services and innovative forms of welfare undergoing experimentation and development in various European contexts (De Vivo et al., 2018).

This paper aims to describe the importance of networks between different actors of the agricultural system and how these could favour the process of rural transition, i.e. how SF stimulates innovation in the welfare system. The work takes its cue from the first results of a study conducted on the role that a public body, the Italian National Rural Network (NRN), can play in fostering the creation of networks within a group of heterogeneous subjects (agricultural entrepreneurs, farmers' unions, public officials, young students, health and social workers) who met thanks to the events (study visits and summer schools) organized by the NRN (Borsotto et al., 2019).

The purpose of this study is to investigate networks and their efficiency within a group of actors that are involved in social farming in Italy.

Materials and methods

The research carries out a qualitative analysis in two steps to describe Italian SF operators and the networks among them.

The study involved a group of Italian SF operators who participated, between 2016 and 2017, in a questionnaire with the CAWI (Computer Assisted Web Interviewing) methodology carried out by the Italian National Rural Network in collaboration with the National Institute for Public Policy Analysis (INAPP) (CREA-PB, 2017). The decision to use the CAWI survey strategy is linked to considerations about the nature of the target population, composed of subjects who are familiar with the use of the Internet (Bosnjak et al., 2008), but also about the advantages offered by the CAWI methodology compared to other methods of administering questionnaires (e.g., lower costs, timeliness in collecting information, low risks of conditioning, insertion of data collected directly into the matrices, possibility for respondents to resume the questionnaire when filling in).

About 1,200 subjects distributed throughout the Italian territory were invited to participate in the questionnaire through an e-mail; these subjects were identified as "potential" SF operators. The list was drawn on information contained in official websites and publications. The *Forum Nazionale Agricoltura Sociale (FNAS)* and *Rete Fattorie Sociali* also provided a list of their members.

The 1,200 actors involved in the CAWI survey were different in terms of legal form, agricultural production, social activity and therefore they were divided into four main categories:

agricultural farm/enterprises (individual enterprises, agricultural companies, agricultural cooperatives);

social cooperatives (A-type, B-type and A+B type[66]);

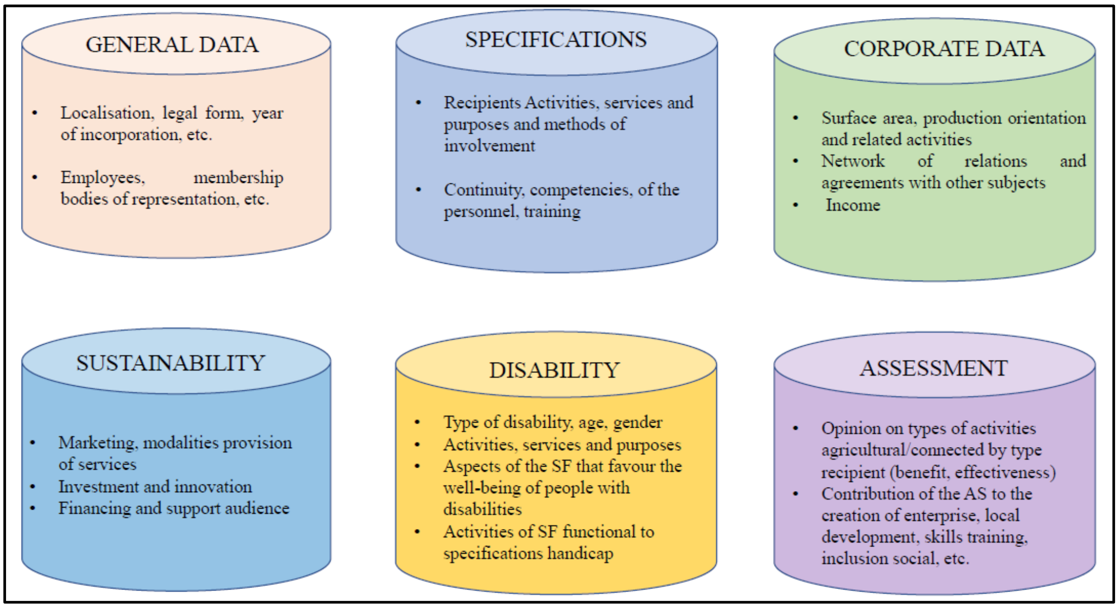
public bodies (local health authorities, hospitals, prisons, schools, universities);

other subjects (Unions' Farmers, associations, Local Action Groups (LAG), consortia, rehabilitation centres, communities and religious institutions).

In order to define the objectives of the survey to be carried out through the questionnaire, a discussion with a group of experts in social farming at national level was organized. Experts from public research (*Istituto Superiore di Sanità*, University of Pisa, University of Tuscia, University of Perugia) defined the main areas of investigation and the structure of the questionnaire.

The questionnaire mainly contained closed-ended questions. It was divided into six different sections aimed at collecting general information, the farm structure, the agricultural and social activities, but also specific aspects such as the economic sustainability of the SF experiences, the specificity of the activities aimed at people with disabilities, the opinions on the effects of SF and the critical points that operators encounter in the implementation of activities (figure 1).

Figure 1 - Structure of the questionnaire CAWI



[66] Social cooperatives (SC), defined by the Italian Law no. 381 of 8th November 1991, aim at "pursuing the general interest of the community in the human promotion and social integration of citizens". SC are classified according to the way in which they pursue the non-profit purpose and are divided into SC of type A), i.e. dedicated to the "management of social, health and educational services", and SC of type B), which provide for the "performance of different activities - agricultural, industrial, commercial or service - aimed at the employment of disadvantaged people". SC can also be of the mixed type, i.e. A and B. Unlike other types of cooperatives, SC may have voluntary members (at least half of the workers) and, if type B, they must have at least 30% of disadvantaged workers.

Source: Our elaboration on CREA-NRN data

Of the 1,200 "potential" SF operators, 411 answered the questionnaire, but the response rate is 31%, as 367 questionnaires were filled in and completed (Weimiao and Zheng, 2010). Some questionnaires presented problems that did not allowed their use (such as incomplete questionnaires or respondents not carrying out SF activities). Even if they do not represent a statistically significant source, we have used these data to give an articulated and differentiated picture of social farming in Italy.

Social relations, networks and values influence the functioning and development of societies and social capital. Several authors have scientifically defined (Acciani et al., 2009; Cristini et al., 2012) and measured social relations between subjects, groups, organizations or other entities involved in processes of exchange of goods, information and knowledge (Wasserman and Faust, 1994).

We have mapped and measured the links (formal and informal) that some of these 367 realities have created by using the Social Network Analysis (SNA). SNA is the mapping and measurement of relationships and flows between people, groups, organizations and other information/knowledge entities (Krebs, Holley, 2002). It plays a role of organizational investigator by uncovering the real networks, which operate below the formal organizational structure and indicating ways of improvement. The SNA also allows to describe the complexity of the relationships, as well as to highlight the distinctive elements of the network, the strengths and weaknesses and the most important nodes (Trobia and Milia, 2011).

The relational data, necessary to determine and make visible the cognitive map of relationships, were obtained through the analysis of 112 questionnaires received. The reports were then classified by categories of homogeneous actors (social workers, farmers, public officials, etc.). The data collected were then organized through the creation of a square symmetrical matrix, called the adjacency matrix (one mode), in which the links were represented by dichotomous values. The matrix represents the playing field in which all the actors are identified. For the following mathematical elaborations of the data, the UCINET software (Borgatti et al., 2002a) version 6.685 was used, while for the transposition of the matrix into graphs, the NETDRAW software (Borgatti, 2002b) version 2.168 was used. The latter allows, even if at an intuitive, non-formalized level, the observation of the relational structure represented by the graph called sociogram.

The results of the analysis help to highlight the elements that make networks efficient and those that hinder their good functionality; in particular, the SNA allows to:

understand the lack of connections between groups/subjects;

highlight the areas of possible improvement regarding the flows of knowledge and information;

recognize the categories of subjects/individuals that play a central role in the networks or that can have a catalytic function towards other categories of subjects;

intercept the categories of subjects/individuals who show the greatest difficulty in participating in the networks;

identify the nodes that make the circulation of information difficult;

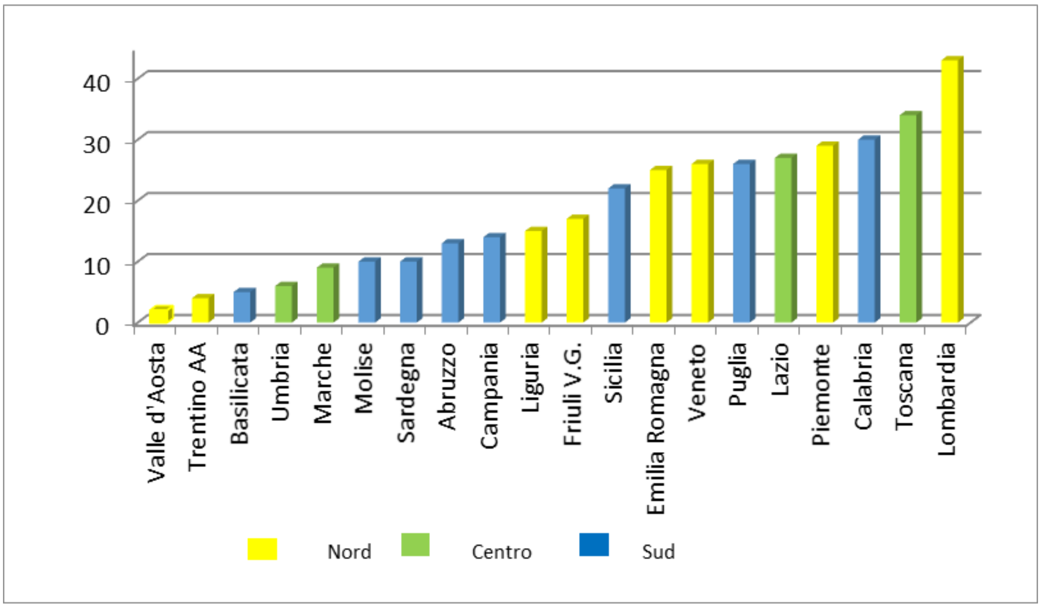
raise awareness of the importance and effects of informal networks.

The analysis provides useful indications not only for further research and analysis activities, but also to better finalize the activities of support carried out by NRN aimed at networking the subjects who work in SF and therefore to improve the exchange of knowledge (Albanese et al., 2012).

Sample description

The largest number of questionnaires were completed in Lombardia, Toscana and Calabria while the least representative regions are Valle d'Aosta and Trentino Alto Adige (Figure 2).

Figure 2 Number of filled questionnaires at regional level



Source: Our elaboration on CREA-NRN data

The realities surveyed are mostly newly established: social farming activities have been activated in almost 80% of cases since 2005 and only 18% are the firms that started social farming before 2000.

The sample is characterized by a high farm size of about 25 hectares, a value significantly higher than the average farm data from the 6th General Census of Agriculture of ISTAT in 2010 (7.9 ha) and a preponderance for the classes of UAA with more than 50 ha (76%), whose area is managed by 7% of farms. In contrast, 58% of farms have only 5% of the total UAA. About half of the UAA is rented, more than double the percentage of the property, which is also related to the legal form of the realities of SF, among which social cooperation is predominant (representing 46% of the total sample, with a prevalence of B-type cooperatives). There are forms of free loan of both public and private land, as well as management of confiscated land from the mafias, predominantly in Southern Italy. Free loan is a method of management that allows the use of abandoned land, with the aim, among others, to protect degraded areas in order to stem the loss of productive land, but also the neglect of the territory, one of the main causes of hydrogeological instability. Urban and peri-urban gardens respond to this aim and to an increasingly present need to self-produce food with a view to eco-sustainability and quality.

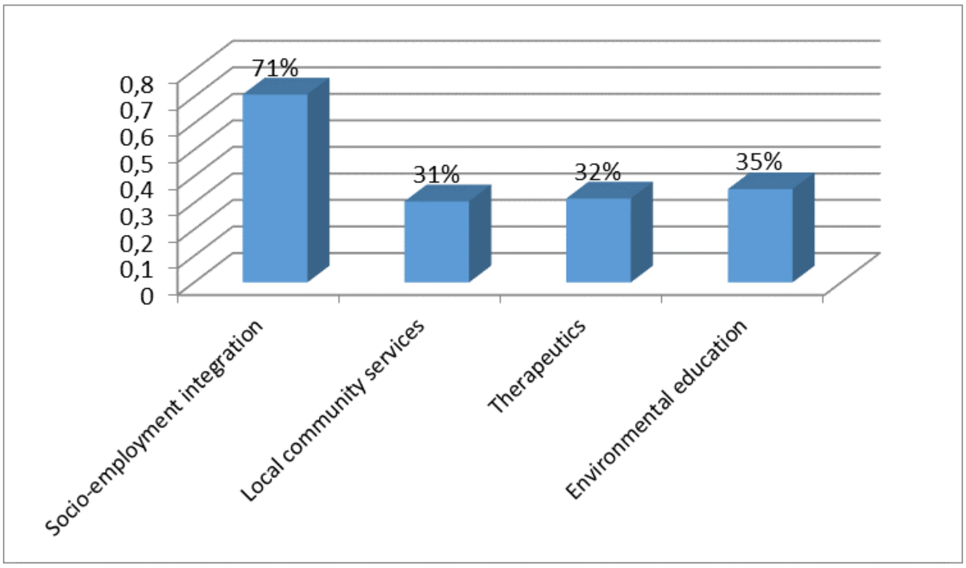
The analysis of the questionnaires clearly shows a correlation between the practice of social farming and the adoption of natural farming methods (organic or biodynamic), adopted by 68% of farms. The protection and enhancement of resources, with respect for the environment, animal welfare and consumers concerns are in fact the prerequisites for sustainable development as a model and lifestyle, able to become a reference point not only for those who work in this field, but also for citizens and users.

The distribution channels of agricultural products from SF are differentiated: more than 60% sell directly on the farm, more than 35% to Solidarity Purchasing Groups (SPGs), more than 32% in the farmers markets and 22.3% in the catering sector, 8.5% in organized distribution and 7.0% in wholesalers.

The agriculture-related activities of the farm represent an important element in the organization of the realities of SF and, in many ways, represent the heart of it. As highlighted in other studies (Lanfranchi et al., 2015), multifunctionality includes all the functions attributable to agriculture: from socio-cultural to environmental, from transport to educational and cultural services. Some of them are explicitly identified by the Law (educational farms, environmental education, etc.), others are useful channels for the employment and social inclusion of vulnerable sections of society. On average, each of the analysed realities carries out more than 2 connected activities, with a prevalence of farm shops and educational farms. These activities are more present in social cooperatives, as the maintenance of green areas, due to the high percentage of work inclusion activities.

The analysis of the activities carried out, classified according to art. 2 of Law 141/2015, shows that social and employment integration of disabled and disadvantaged workers is the main one, present in 71% of the sample, while the other three types are represented in a similar percentage of the sample (figure 3).

Figure 3 Different services offered (%)



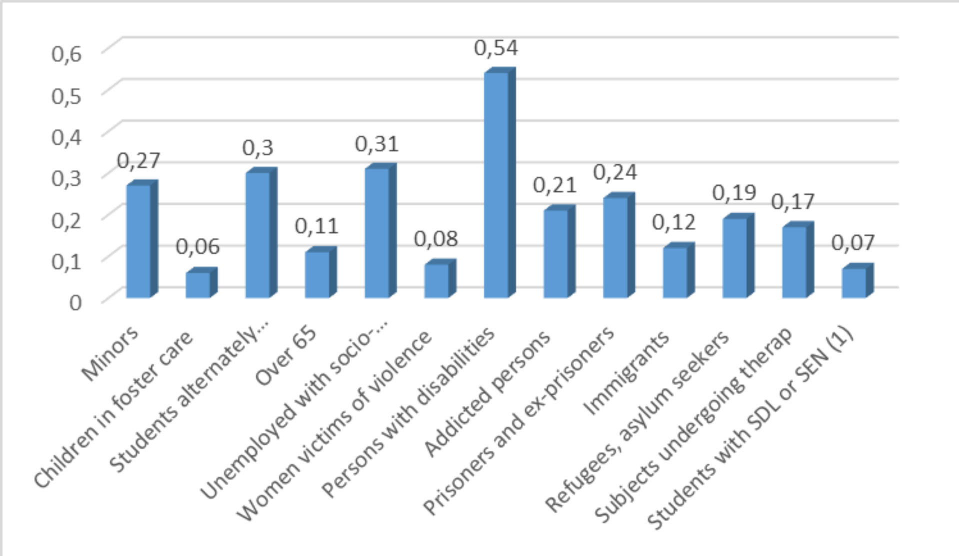
As well: multiple choice question

Source: Our elaboration on CREA-NRN data

The activities are mainly carried out directly by the structure (79% of cases). The external subjects involved are primarily social cooperatives (28%), which have different professional backgrounds within them, followed by voluntary associations, which play an important role in social aggregation and listening to needs.

As is well known, SF addresses the weaker sections of the population, from minors to the elderly, from refugees to prisoners, with a variety that often derives from the specific needs of the contexts in which it operates. The activities are aimed at more than one type of person and 54% of the sample carries out activities aimed at people with disabilities, a percentage that is much higher than that of the other categories (figure 4)

Figure 4 Recipients of SF activities



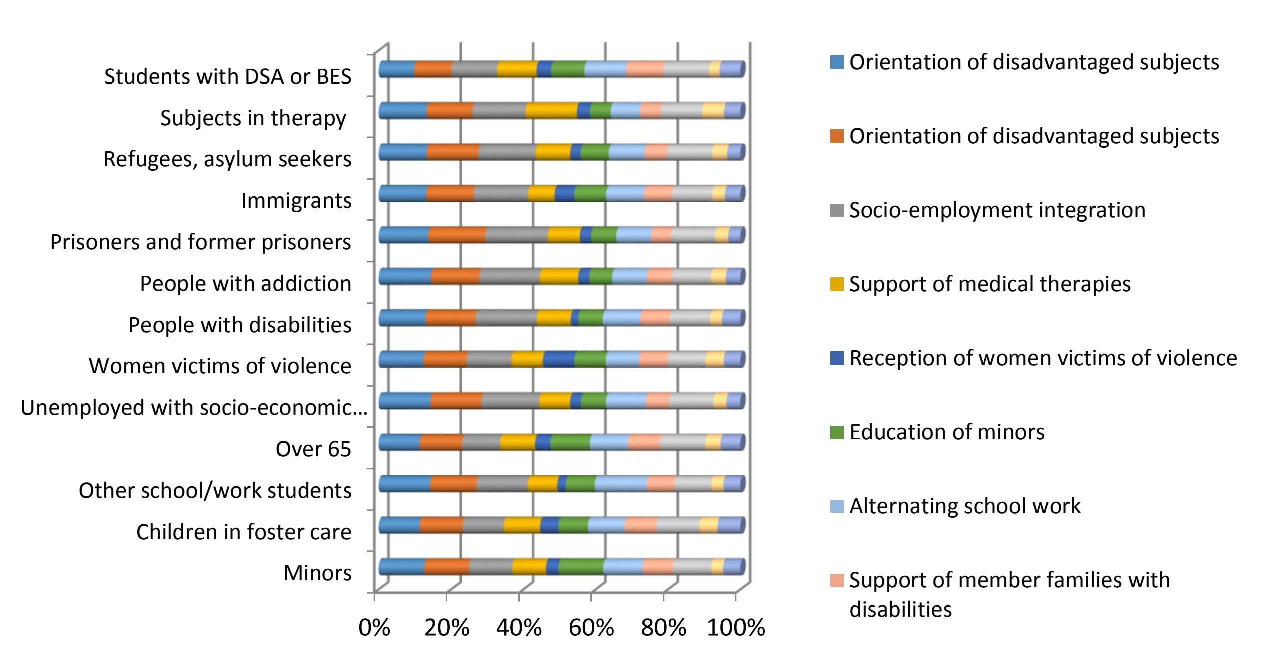
As well: multiple choice question

SDL Specific learning disabilities; SEN Special educational needs

Source: Our elaboration on CREA-NRN data

The services offered are many and respond to different needs, some more specifically oriented to training and employment, others aimed at supporting socially excluded people and families with members with disabilities. Figure 5 shows, for each type of recipient, the percentage of services used.

Figure 5 Services offered by type of recipients of SF activities (%)



Source: Our elaboration on CREA-NRN data

The services present in all categories of recipients are counselling and training, both important for disadvantaged people, as they allow to acquire skills and information guiding life and work paths. Social and work integration also play a significant role.

Another element investigated in the survey is the way in which the recipients of SF activities are involved in them.

Networks in social farming

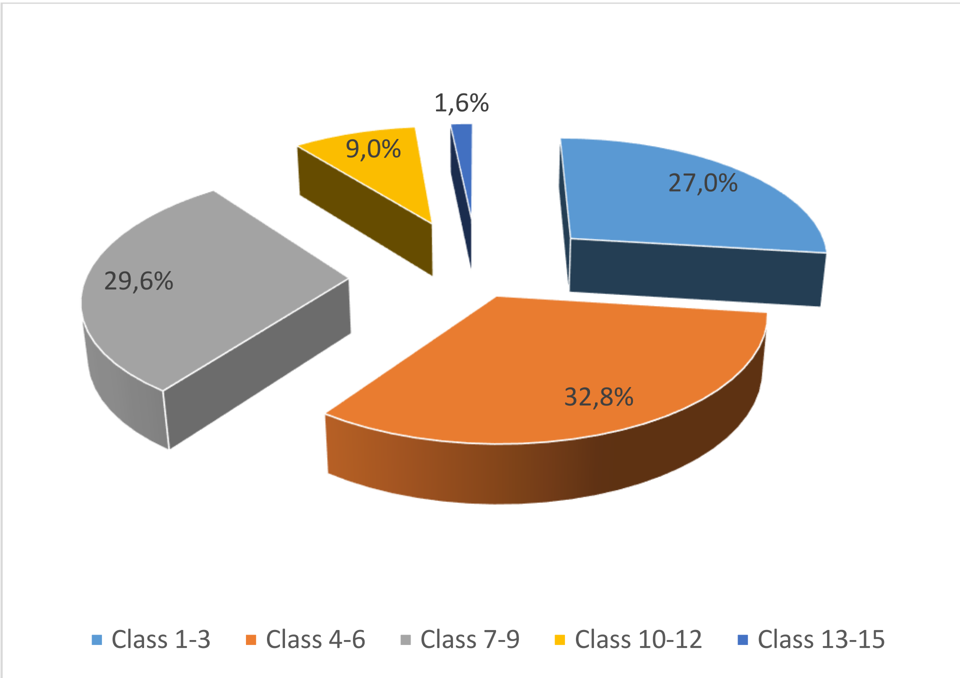
Social farming is a very complex activity that requires the contribution of different skills and expertise. More than 85% of social farms have adequate staff to carry out the activities but the remaining 15% needs external subjects. Usually those who turn to external subjects identify one or two interlocutors (75%), however there are also cases where the number of relationships increases considerably, up to 7 experts.

The legal form of social farms influences the use of external services. However, cooperatives, which are the most widespread form, make less use of external services, while farms, partnerships, corporations and other associations turn more to the outside. This is because cooperatives have more complex structures and more social skills.

The most involved external subjects are cooperatives (31%), in particular social cooperatives (27%). Other important entities are the associations (21%), individual companies (11%), local authorities (8%), health authorities (7%) and penitentiary institutions (7%). People that work in social farming have a good organizational structure and developed skills and in this sense the world of cooperation is the most representative.

In addition to relations with external subjects for the implementation of SF activities, the relationships not strictly connected to the practices of the SF are fundamental; they are established with actors through different types of agreements. The networks are complex due to the type of agreements and the number of subjects involved. Social farms enter into agreements at the same time with different categories of actors. The agreements mainly range from a minimum number of 2 to a maximum number of 9 with 87% of the sample falling within this range. The most representative class, with 33% of the sample, is the one that provides for relations with a few subjects ranging from 4 to 6, followed by class 7-9 (30%) and class 1-3. Finally, even if numerically less consistent, 11% of the sample is at the centre of a network with more than 10 relationships (figure 6). The relationship is, therefore, a characteristic element of SF and the opening to the outside of social farms emerges in a significant way. On the one hand, these farms need a continuous exchange of professionalism, services, experiences, ideas and, on the other hand, they focus on themselves the attention of the surrounding territory as they represent a place where other local actors and the population actively participate in processes of social growth.

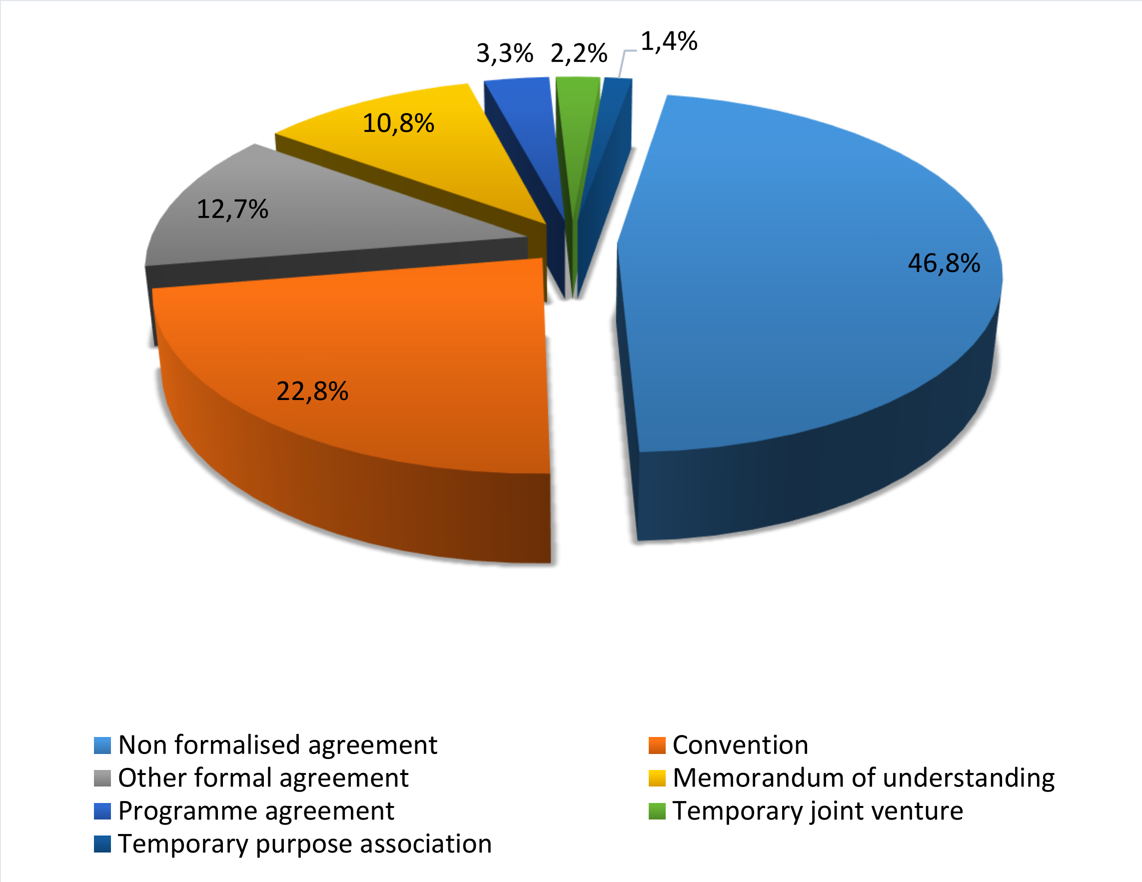
Figure 6 Network agreements in classes



Source: Our elaboration on CREA-NRN data

The most common form of agreement is the non-formalised one (47%) followed by the convention (23%), "other formal agreement" (13%) and the memorandum of understanding (11%) (figure 7). Programme agreements, temporary joint ventures and temporary purpose associations, which represent more articulated types of agreement, are marginal forms, totalling only 7% together. The form of agreement differs from the subject with whom it is stipulated: for the more "institutional" external subjects a formal type of contract prevails and in particular the convention (health agencies, social services, penitentiary offices, schools, territorial support centres), while for the other subjects the non-formalised agreement prevails.

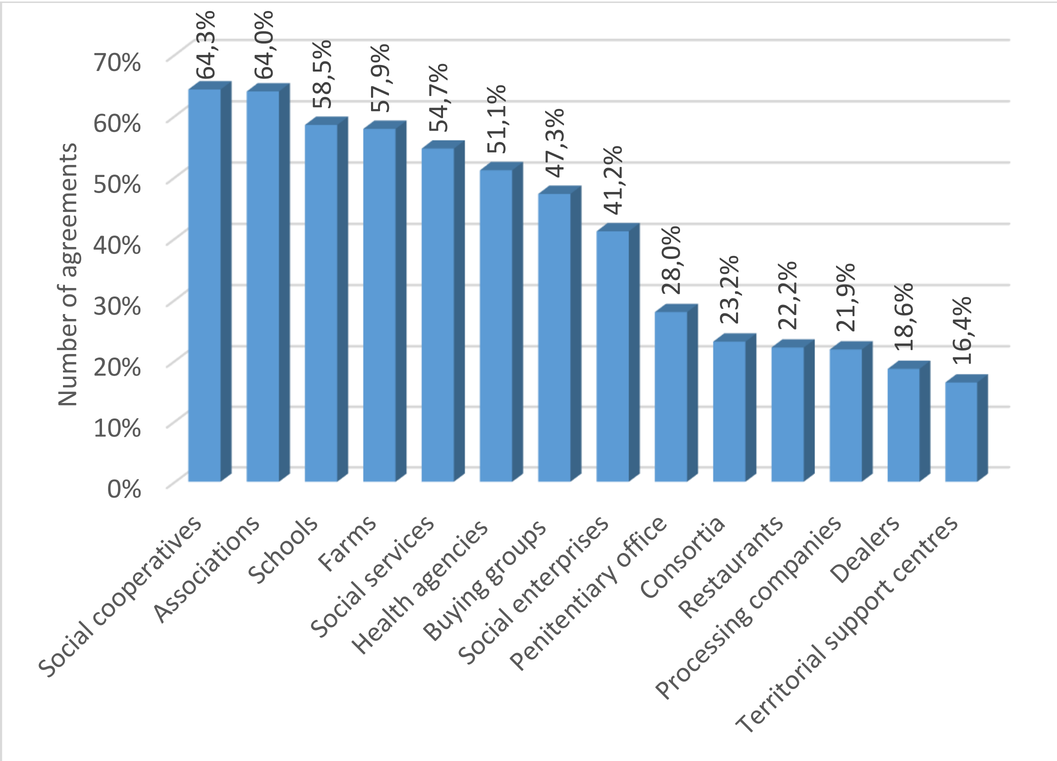
Figure 7 Types of network agreements



Source: Our elaboration on CREA-NRN data

Social farms have the greatest number of relationships with social cooperatives and associations (65%). Furthermore, almost 60% of them have relationships with schools and farms, social services and local health agencies exceed 50%. A significant number of subjects have agreements with buying groups (47%) and social enterprises (41%). The other actors involved in the network agreements represent less than 30% of the sample as shown in figure 8. Cooperation, in particular social cooperatives, and associations represent a frequent operative mode in the world of SF and main relationships take place with subjects who share the same inspiring principles and who are often involved in similar activities.

Figure 8 Network agreements by subject type



Source: Our elaboration on CREA-NRN data

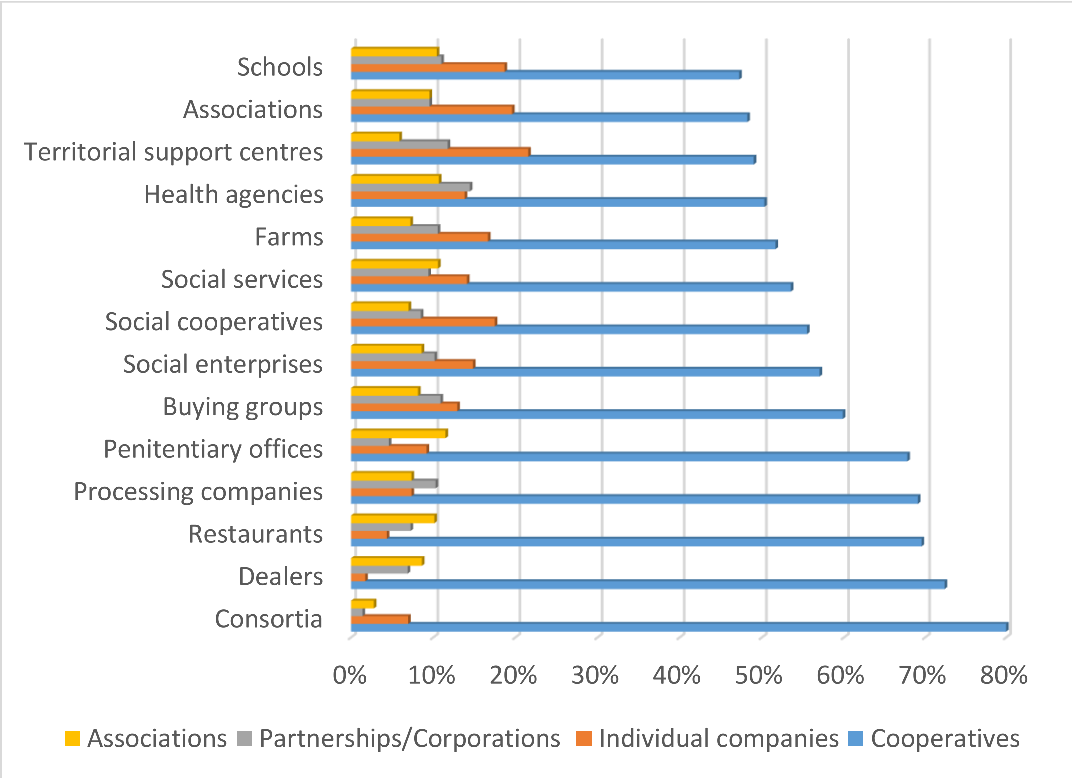
Non formalised agreements are the most common way for social farms and are used mainly with those who connect the world of SF with the consumption. Buying groups and restaurants establish almost 80% of the time direct relationships with social farms using this form of agreement. This particularity of the social farms-consumers connection is highlighted by the incidence of this mode of agreement also for dealers and processors.

The formal agreement is the second mode chosen for the agreements and represents almost a quarter of the overall agreements. Most of the actors who work on the territory and who have a public structure operate with formal agreements and in particular through the instrument of the convention.

The other modes of agreement are little used and are significant only for some types of subjects.

The analysis of the legal nature of social farms shows the relevance of some categories in terms of aggregation capacity. A predominant role is played by social cooperatives which, together with other forms of cooperatives, are at the centre of a network that represents the 56% of relations. An important role is played by individual companies (14%), partnerships/corporations (10%) and associations (9%) These four main SF realities are therefore able to build close relationships with the other SF actors, creating very articulated networks (figure 9).

Figure 9 The importance of the four main legal types of social farms in the networks



Source: Our elaboration on CREA-NRN data

SF takes on different forms and dimensions, depending on the needs and resources of the territory and with the aim of building development paths in order to provide services and improve the conditions of the local community. These features are present in an almost independent from the legal form and the role held.

Results

In this paper we wanted to investigate the role of the networks that "social farms" have with farmers' unions specialised in social farming.

From the 367 questionnaires collected, only 112 social farming operators (agricultural enterprises, social cooperatives, etc.) with at least two active ties with other representative actors (14, big and little, famers' unions) were identified.

In Italy, the bureaucracy in agricultural sector revolves around farmers' unions. Some of them are large in terms of numbers of hectares of the farms associated, but also with reference to workforce size of the farms (*Coldiretti*, *Confagricoltura* and *Confederazione Italiana degli Agricoltori*) and others are less large (*Copagri*).

There are also some representative structures not specialised in the agricultural sector but mainly in the cooperative and associative world.

In social farming there are currently three large representative associations: *Forum Nazionale Agricoltura Sociale (FNAS)*, *Rete Fattorie Sociali*, and *BioAgricolturaSociale*, the latter was set up in 2018 and is therefore not part of the organisations surveyed in this work. *Coldiretti* put together the farms that operate in Social Farming activities under the *Campagna Amica* brand.

The survey's descriptive modalities and results were presented in the previous chapter. Concerning the "global" properties of the network, the degree of cohesion of the network was verified through the density index. This index is given by the ratio between the number of ties existing in the network and those that can be activated. The density has a range of variation between a minimum value of "0", which indicates zero density (network completely disconnected) and a maximum value of "1", which indicates the extreme density where all potential ties have been activated. The analysis showed a very low value of density (0.034); in fact, representing 530 activated ties out of a total of 4,206 potential relationships between the 126 actors surveyed. The value of the density is inversely proportional to the size of the network. In fact, the ties of an actor do not grow as the number of nodes in the network increases and therefore the measure must be related to the size of the network.

In order to deepen the analysis and increase the understanding of the network structure, some of the main relational indicators available for the mathematical analysis of the actors have been used, which allow to identify the position and characteristics of each node in the network. This network centrality measurement has been carried out by using an index, called centrality index, which is aimed at measuring the structural position of one node in relation to the others. The centrality represents one of the main objectives in the empirical analysis of social networks, as it allows to define and identify the positioning of a specific subject in its network in purely relational terms (Cordaz, 2005).

From the sociogram (fig.10) emerges, moreover, the presence of some larger nodes that present a high degree value (*Forum Nazionale Agricoltura Sociale (FNAS), Rete Fattorie Sociali, Coldiretti, Confagricoltura, Copagri and CIA)*. The degree of a node, called *d(ni)*, is given by the number of lines adjacent to it. The degree of an actor means the number of relationships it has. According to this indicator, the greater is the number of relationships that an actor has, the more central is its position in the network (Wasserman and Faust, 1994).

Centrality degree is an analytical index that varies from "0" to "1" (minimum and maximum centrality) and measures how much a node is connected. According to this mode, the greater centrality of a node is determined by the number of relationships that each node has with the others, calculated on the basis of the relationships that can potentially be activated.

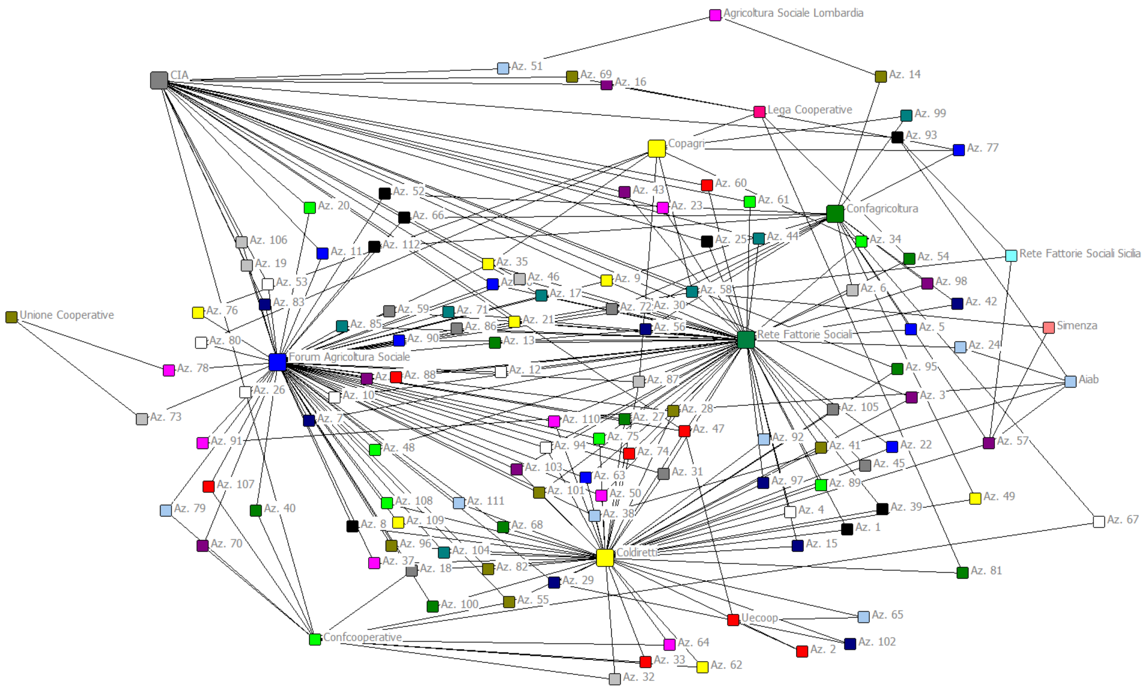
The formula is:

$$CD\,(ni) = \frac{d(ni)}{n-1}$$

where *CD* stands for centrality index calculated on degree; *d(ni)* indicates the degree of the node; *n* represents the number of nodes making up the grid. In a simple graph the degree varies from 0 (isolation) to n-1 (linked to all the other nodes). It is evident that a greater degree corresponds to a greater integration of the node in the network (Marcolin, 2007). The mode centrality degree shows that the most involved actor in connections with SF enterprises is the *Forum Nazionale Agricoltura Sociale (FNAS)* with a level of 0.540, followed by the *Rete Fattorie Sociali* with 0.468, *Coldiretti* with 0.397 and *Confagricoltura* with 0.143. This index shows the potential communication activity of a node: greater is the possibility of communicating directly with the other nodes, greater is the centrality.

The analysed network has not proved to be very cohesive, due to the lack of ties between many of the actors. This value is influenced by the presence of social actors who interact little with the others, or who do not interact at all. Moreover, it is an active and inclusive network characterized by a certain amount of redundant links that can be poorly efficient and an obstacle to its further expansion. With respect to this network, some trade unions play an important role in representing farms operating in the social farming sector.

Figure 10 - Sociogram



Source: Our elaboration with UCINET software version 6.685 and with NETDRAW software version 2.168 on CREA-NRN data

Moreover, through the SNA, within the Italian Social Farming Network (ISFN), all the subgroups of at least 3 actors in which each node is directly connected to the others have been identified. In the ISFN sociogram (figure 10) each actor is represented by a square (node), while the relations between subjects are represented by bi-directional lines, being the collaboration relationship a reciprocal one. The figure shows the relationships within the structure. *Forum Nazionale Agricoltura Sociale* and *Rete Fattorie Sociali* represent the central nodes that have activated all ties through their institutional activities.

Concluding remarks

Literature highlights how strategic is the creation of networks in the performance of Social Farming activities. These are implemented through cooperation between actors with different professional skills and abilities and require networking between participants. Interactions between the components of Social Farming activities are fundamental for the internal decision-making processes of the network.

The survey conducted on a group of subjects who develop SF has shown how often the search for professionalism takes place outside the organization through both formal and more often informal agreements. Networks are formed not only between subjects with different skills (agricultural and social) but also between organizations that carry out similar and complementary activities and find in bodies such as *Forum Nazionale Agricoltura Sociale and Rete Fattorie Sociali* important nodes to improve their activities and to implement new networks.

The SNA has allowed the identification of the subjects who, by centrality and interposition, are potentially very much representative of Italian social farming movements. The network analysed is not very cohesive due to the lack of ties between many actors; however, it is active and inclusive, even though it is characterized by redundant ties that may be inefficient and may hinder its further expansion.

In the future, it would be interesting to strengthen and support the creation of a specialised network aggregating stakeholders in order to activate initiatives concerning education, information, projecting, finance, etc. Such a network would play a crucial role in facilitating the matching between demand and supply of Social Farming services and contribute to the local development of territories.

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THE PARADOX OF FARMER EMPOWERMENT AND ON-FARM DIVERSIFICATION IN FRANCE

Sylvie Lupton[a], Ilyess El Karouni[b]

[a] UniLaSalle, Research and teaching Chair "Risk management in agriculture" UniLaSalle-Groupama Paris Val de Loire, France
[b] University Paris 8, France

Abstract

This paper aims at understanding to what extent on-farm diversification contributes to empowering farmers in the food chain. In this respect, a qualitative enquiry was conducted in the North of France in 2019 among forty five farmers transforming and directly selling their own products (poultry, cereal, market gardening, wine and bovine meat sectors). The paper aims at analyzing how these farmers were more empowered. After having clarified the concept of empowerment in economics and stressed what has been developed in the literature on farmer empowerment, the results of the qualitative analysis are developed. We find that farmers now have the ability and freedom to fix the prices according to the costs of production and are no more dependent on other actors of the food system (mass retailing, food industries, trading companies) and world market prices. They usually observe that their income has risen since the development of on-farm processing and selling (market empowerment). They also enjoy and feel proud to sell their own products and exchange with consumers (non-market empowerment). That being said, one can also observe some shortcomings. One of the most important ones is the time farmers spend processing and selling their products. After having analyzed these empirical findings, we shall question the very concept of farmer empowerment: to what extent do farmers actually gain control over their lives?

Introduction

Empowerment is a crucial concept and is particularly relevant in a farming systems approach that considers the farmer as the central actor (Darnhofer, Gibbon and Dedieu, 2012). This concept has gradually gained pride of place in the social sciences since the 1960s. Over the decades, it has been used with reference to oppressed groups (see for instance, Solomon, 1976). Empowerment was then seen as the result of a pragmatic endeavor to change the world by fighting social and economic injustices, especially when analyzing empowerment of women farmers, and farmers in developing countries. However, there seems to be a gap in the literature regarding farmer empowerment in developed countries. With growing liberalization of agricultural markets, and rising influence of mass retail and food processing sectors worldwide, farmer empowerment seems central in understanding agricultural systems in developed countries.

Our paper's objective is to analyze to what extent on-farm diversification (processing and direct selling) contributes to French farmers' empowerment. The paper first clarifies the concept of empowerment in standard economics and in a capabilities approach. The results of the qualitative survey based on 45 qualitative semi-structured interviews to farmers processing and/or directly selling products in the North of France are then explored, in order to understand which market and non-market capabilities were enhanced. We shall tackle one major paradox of farmer empowerment: the additional workload generated by on-farm diversification, that could be at the core of the limits to farmer empowerment.

1. A clarification of the concept of empowerment

An indication of the growing success of the concept of empowerment is the fact that it has become a public good, used in various fields from social work, gender studies, minority studies, to development studies. Empowerment literally refers to the process through which a person or group gains power[67]. After having briefly examined how mainstream economics views empowerment, the capabilities approach shall be addressed. The latter approach is chosen as the framework to grasp farmer empowerment.

1.1. Market empowerment: the mainstream economics view

Getting empowered is understood by mainstream economics through a quantitative, tangible lens. Actually, mainstream economics[68] does not mention people's empowerment *per se*. From this viewpoint, gaining power over people's own affairs can be achieved through an increase of their utility or their income. This strand of thought considers each individual as a rational *homo economicus* who is constantly trying to improve his/her position and therefore mechanically responds to incentives (notably price incentives), in a rational and hedonistic manner. When prices are too low or costs are too high, entrepreneurs have no incentive to grow their business and withdraw from the market. As for demand, it will in turn increase. This situation will cause prices to rise allowing the market to return to equilibrium. When prices are higher, the reverse occurs. These are basic supply and demand rules. Free markets are therefore the best way of organizing economic life. They allow to maximize economic welfare, usually measured in terms of utility or income.

Another way of tackling empowerment within this framework is to consider market power, that is to say the power over pricing, either from the demand or the supply-side. Under perfect competition, neither the buyer nor the seller has such a power. They are all price-takers and cannot raise or lower the market price.

There is evidence of empowerment through the market, either by the participation in it or by benefiting from a power over it (El Karouni, 2012). In the case at issue, obviously, farmers who have sufficient market power to be able to fix prices in a manner which is independent of the behavior of their competitors, increase their revenue and therefore have more power over their lives. It is then in their best interests to acquire or reinforce their market power.

1.2. The capabilities approach

The concept of capabilities was first devised by Amartya Sen in his 1979 Tanner Lecture (Sen, 1980). Sen criticized standard economics' sole focus on utility and income as tools for assessing well-being. He advocates a vision beyond utility, taking into account the individuals' capacity to act. Capabilities are a set of 'beings' and 'doings' that are available to a person. So, from this viewpoint, getting empowered means having access to a greater range of opportunities either in terms of 'beings' or 'doings' (the ability/opportunity to be or to do).

From the 1990s, people's empowerment in terms of capabilities explicitly appear in the specific objectives of some international organizations. The World Bank defines empowerment as such: "Empowerment means enhancing the capacity of poor people to influence the state institutions that affect their lives, by strengthening their participation in political processes and local decision-making" (World Bank, 2000: 39). World Bank (2002) gives a more precise definition of empowerment: "Empowerment is the expansion of freedom of choice and action. It (…) is the expansion of assets and capabilities of poor people to participate in, negotiate with, influence, control, and hold accountable institutions that affect their lives" (Deepa, 2002: 14). Of course, this report mainly focuses on the elimination of poverty, especially in poor countries. It however allows a broad understanding of this concept, that we shall use to tackle farmers' empowerment.

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[67] We adopt Weber's definition of power as the capacity to impose one's preferences to others albeit their resistance (Weber, 1954).

[68] We refer to mainstream economics as neoclassical theory.

2. Farmer empowerment and on-farm diversification

2.1. Farmer empowerment and on-farm diversification

Farmer empowerment literature is essentially based on developing countries (Wouterse, 2019) from the perspective of fair trade (Kruger and Du Toit, 2007; Dubuisson-Quellier and Lamine, 2008; Valkila, Haaparanta and Niemi, 2010; Guijt and van Walsum, 2016) and women farmers (Porter and Zovighian, 2014; Annes and Wright, 2015; Wright and Annes, 2016). The latter authors' research allows a better understanding of farm women's empowerment through on-farm diversification in the United States (Michigan) and in France. Wright and Annes (2016) analyze farmer empowerment women farmers' empowerment in Michigan in a sociological perspective. They define empowerment as a "multi-dimensional process constituting the 'power to' realize one's goals, the opportunity to exercise 'power with' others, and the ability to find and nurture 'power within' the self" (2016, p. 545). Based on 32 qualitative semi-structured interviews in 2013, the authors find that these women have gained autonomy in the decision-making process and control over their farm, but may still often be dependent upon male incomes and may conform to culturally expected gender roles.

As for research on farmer (men and women) empowerment in developed countries, Milone and Ventura (2018) illustrate case studies in England, the Netherlands and Italy in which farmers take back control over resources and products leading to greater autonomy. Needless to say, more research is needed to understand farmer empowerment in developed countries.

2.2. Research methods

The research was based on 45 qualitative semi-structured interviews to farmers processing and/or selling products themselves in five different food sectors (poultry, cereal, market gardening, wine and bovine meat sectors) in the North of France[69]. The goal was to understand what on-farm diversification changed in economic (income, workload) and social/psychological terms (satisfaction, self-esteem). Farmers were essentially identified through internet sites[70] and snowball sampling. The selection of farmers interviewed was based on a typology capable of encompassing the variety of transformation and direct sales alternatives (on- and various direct sales such as off-farm processing, farm gate sales, resellers, farm stores…). Table 1 in annex 1 illustrates this variety with the typology of cereal growers selected.

The interviews conducted between January and April 2019 contained approximately twenty questions based on topics such as farm history, organization (employees, workload…), motivations to diversify, and how farmers defined the economic and social success or difficulties of on-farm diversification. The interviews generally lasted from one to two hours and were tape-recorded and transcribed. An inductive

[69] Interviews were conducted by 4th-year student engineers from UniLaSalle Beauvais (France), under the general supervision of Gilles Moreau. Respectively twelve farmers were interviewed in the cereal sector, nine in the bovine meat sector, eight in the poultry sector, eight in market gardening activity, and eight in the vine sector. All names have been changed in order to respect the anonymity of farmers interviewed. Verbatim were translated from French to English by Sylvie Lupton. As map 1 in annex 1 indicates, interviews with independent winegrowers were conducted 20 km around Chablis, situated in the North-east of France. This region was chosen as there is no wine production in the Northern part of France (Brittany, Normandy, Picardy and the Nord-Pas-de-Calais regions).

[70] Internet sites such as Bienvenue à la Ferme (https://www.bienvenue-a-la-ferme.com/, a site grouping farm gate sales that have the same logo "Bienvenue à la ferme") and Acheter à la source (Buying directly https://www.acheteralasource.com/) allowed a broader selection of different ways farmers use to transform products and sell directly (farm gate sales, AMAP that are consumer associations supporting small farming, farmers stores…).

method was used, and each transcript was carefully scrutinized. This enabled to highlight different textual themes related to farmer empowerment in terms of capabilities.

2.3. Results of the survey

We distinguish two different kinds of capabilities that were developed by farmers with on-farm diversification, leading to market or non-market empowerment.

2.3.1. Market empowerment

One capability that is predominantly mentioned is the ability to fix prices, and not depend on world market of bulk price fluctuations, or intermediate actors. In other words, farmers that process and/or sell directly to consumers are empowered in decision-making: they choose the price, marketing channels (internet, consumer associations, on-farm shop, producers' shops, …) and to whom they want to sell. As farmers create a niche market, they process and sell their products with no intermediary, corresponding to a situation of monopolistic competition (Chamberlin, 1933). Each product has its inherent qualities (location, product processed by the farmer, authenticity, taste…), allowing farmers to fix the price. As Denis mentions (cereal farmer) regarding the eggs he sells on his farm, "it's pure craftsmanship. I calculate packaging costs, the time I spend, and I fix the price". Clyde, an independent winegrower (processing and selling bottled wine himself), remarks for Chablis wine: "In bottles, you don't depend on the Chablis bulk market. (…) The bottle, it's the mastery of our sales. We have a real negotiation power".

Communication skills are another interesting capability developed because of the direct interaction with the consumer. The farmer therefore adapts to consumers' desires regarding the variety and quality of products sold (horizontal and vertical differentiation). Moreover, on-farm processing develops knowledge and skills on the whole value chain. Ted (cereal producer who processes his wheat into flour) acquired skills on the quality of different wheat varieties: "I surprise myself talking about wheat like a winegrower talks about his grape variety, because from one variety to the other, you don't get the same results". Hence, quality is at the center of on-farm processing and direct selling. Farmers often mention consumers asking them if their products are organic, which has led some to start organic production. As Octave (organic beef producer and direct seller) mentions: "The advantage of organic food is that it opens doors regarding direct selling (…) Systematically when you sell directly to consumers, they ask if you have organic products". A greater variety of goods is often offered by farmers, following consumers' suggestions. Many farmers selling directly on their farms have stressed the fact that consumers ask them for new recipes, new products which induces them to adapt to their suggestions and to innovate. The closeness farmers have with consumers also encourages them to produce quality products. As Nick, a market gardener (selling his vegetables on his farm) finds: "When we don't do (the job) well, it forces us to do better". Farmers want to build trust with their clients, which seems to reduce potential asymmetric information on product quality. They want to be transparent. Martin, who sells poultry (produced and processed on his farm) observes: "There's a thing: it's trust. I have people who are allergic, in terms of traceability, I need to be clean with people". Finally, producing quality products necessarily creates a sense of satisfaction, as Alfred (wagyu beef producer and on-farm seller) notes: "Producing a product with such quality is gratifying, yes. (…) People know us thanks to that".

The ability to be economically independent is very important for all farmers interviewed. They all earn a living and a positive revenue from processing and/or direct selling (except for one), and this was often the reason why they started on-farm diversification. As Adrian (selling poultry on producers' shops) notes: "the objective when I took over the farm was not to be a slave of my work and to earn a living". Economic independence creates a sense of satisfaction, as Diane (selling her flour on the farm and to dealers) finds: "today, I'm happy, as I'm not going to hide it (…). We get more than 800 euros/ton for wheat processing". Three farmers also emphasize their will to be autonomous from CAP.

Finally, we come to the ability to create employment, thanks to increased revenue. This is a source of pride for farmers. Here market and non-market capabilities are embedded. Three farmers have employed on their farm thanks to on-farm diversification, and they express a certain pride in this. Ronald who sells organic vegetables on his farm and through a vending machine expresses his satisfaction: "we're happy about the fact that our way of working creates jobs, that's essential for us".

Yet, probing transcripts in terms of capabilities allowed us to understand that they are intertwined. It is therefore difficult, if not impossible, to separate market and non-market capabilities as though they were independent from one another (see figure 1[71]). The fact of being able to fix prices, to be independent from intermediary actors (mass retailing, cooperatives…) and sell quality products due to enhanced communication with consumers nurtures a sense of satisfaction and pride.

2.3.2. Non-market empowerment

When reading and examining the transcripts of the farmers, one notices that on-farm diversification gives a new sense to their jobs. This is common to all farmers' experience. The fact that they process and/or sell directly is very pleasurable and rewarding. This boosts their self-esteem and a sense of accomplishment. In what follows, we identified three main non-market capabilities that they develop, enabling them to develop this empowerment from within.

Interacting with and listening to consumers' requests, creating bonds with them (leading sometimes to long-lasting friendships) allow farmers to adapt to demand and offer a wider variety of fine-tuned quality products. This in turn generates compliments and higher appreciation from consumers that boosts farmers' moral and self-esteem. As Clement, a poultry producer who slaughters and sells his chickens on the farm, witnesses : "what's important for me is what organic food quality brings to people, I'm proud to propose that type of product to my clients, and if they come back, it's because it has a good taste". When Ernest explains his activity processing flour from wheat, rye and einkorn and preparing organic bread, he mentions the new sense of his activities, "that, that has sense to me, yes, and it's sourdough bread, it's a choice on quality".

Farmers also evoke the fact that selling on their farms allowed them to increase their network and be in contact with farmers that they had never met before, even though they lived next doors. This was mentioned by 10 farmers who explained how direct selling widened their network. As Diane (processing wheat and directly selling flour) notes, "There are farmers a dozen kilometers away that I didn't even know, and now that I make flour, I got to know them".

Finally, the work they do is more stimulating and meaningful. Thirty-two farmers mention the fact that the mastery of the product from the raw material to the final product or the fact that they have a wider variety of tasks to do gives them satisfaction. As Herbert, a market gardener who has a fruit and vegetable pick-your-own, underlines: "It's exciting because it's a really complete profession, you must be good in production, in human management, in communication". As for Robert who processes wheat and sells flour and pasta, mastering the whole value chain has lots of sense: "Make no mistake, it really gives sense to our profession. When we started the stone mill three years ago, the first flour we made, I had shivers down the back! (...) All of a sudden, I saw that my profession was different".

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[71] Figure 1 will be more precisely explained during the conference. We shall point out the interactions of different capabilities according to farmers interviewed to demonstrate the embeddedness of market and non-market capabilities.

Figure 1. Intertwined capabilities

Source: figure elaborated by the authors

2.3.3. A paradox: the workload

When delving into on-farm diversification, several authors have mentioned the extra workload due to various activities the farmer has to manage (Aubry, Bressoud and Petit, 2011; Darduin et al., 2013).

In terms of farmer empowerment, this workload can be depicted as a 'paradox of unintended consequences' (Weber, 1922): farmers' empowerment leads them to work more. Put differently, by getting empowered, they also become self-alienated. By self-alienation, we mean the paradox of a situation of subjugation resulting from the empowerment process. Farmers clearly take great satisfaction from their activities, particularly regarding the autonomy, increased revenue, and control they have acquired over their lives they enjoy more. But their on-farm activities (processing, selling, promoting…) also represent more working hours. Some farmers do not have the possibility to create extra employment as this would mean a significant decrease of their own income.

Thirty-three farmers mention the fact that processing and/or direct selling of their products increases their workload. What is more, most farmers don't complain about this workload. This is undoubtedly the paradox of farmers' empowerment. As Herbert mentions "oh, I must be at around 80 hours a week". This market gardener also points out how much he loves his job: "it takes a lot of work and it's really interesting". Apparently, farmers do not stint on their time. This is common to most farmers as only five farmers out of 33 would like to change pace. Ted who processes wheat with his stone mill is particularly dissatisfied as he has an insufficient income with these activities and is tired of the extra workload. Although he and his wife like what they do, they are considering if they should stop farming altogether. Brad who produces beer from his barley would like to work less and create a firm that would require less personal work: "as we have grown older, we are looking for something more comfortable".

It seems that despite increasing workload, most farmers have passion in what they do. Even Hugo, processing and cutting beef on his farm, who nearly suffered burnout, and admits that sometimes he gets tired, also adds he likes working a lot: "you know working 35 hours a week doesn't interest me, I must do the double, actually I don't know how much I work…um…it doesn't bother me". Paula, an independent winegrower does the job from A to Z from production to marketing and assumes this workload: "I do three jobs in one but (…) it's because I want to".

How can one explain this acceptance to work much more, and to not even count working hours for some?[72] In strictly utilitarian and rational terms, one could quickly conclude in terms of disutility to work as much, and even farmers' irrationality. However, if one goes beyond this framework, and observes farmers' behavior and preferences, these are not only guided by reason but also by feelings and passion (Franck, 1988). Rationality combines both emotions and reason. Veblen's thought can also be enlightening in this matter. For him, people are not only hedonistic and rational calculators. Their behavior is also influenced by habits of mind which are themselves driven by 'instincts'. One of these instincts is the 'instinct of workmanship', in other words, the love for work well done (Veblen, 1898), and this is particularly visible in the transcripts.

Conclusory remarks

This paper has scrutinized the empowerment of northern French farmers who process and/or directly sell their products. These farmers have gained power through enhanced market and non-market capabilities. As far as market capabilities are concerned, their activities allow them to fix the prices of the products they produce, transform and sell, and their income is not jeopardized by the fluctuation in world market prices. They are autonomous and no more dependent on other actors of the food system. In the majority of cases, their income has risen since the development of on farm processing (market capabilities). As for non-market capabilities, farming has a new meaning for most farmers. They are proud of selling quality products directly to consumers, and consumers' positive reaction boost their self-esteem. That being said, one can also observe some shortcomings, in particular regarding the excessive workload that most farmers seem to be willing to accept. This seems however understandable if their passion for their work is taken into account. But, this also raises the question of the limits to their empowerment.

This research opens a Pandora's box of questions regarding farmer empowerment. With growing agricultural market liberalization and less financial support on farming activities, farmers have been encouraged to develop value-added activities. They actually gain more from these activities than from their production, but the workload is considerable. What are the long-term consequences of this growing trend in agriculture? Are there growing risks in terms of farmers' exhaustion? Was the Common

[72] When asked about what is important in his value-added activities, Sebastian, who produces and sells beer responds: "Not counting one's hours. If we counted the hours, it would get scary". Alfred, a wagyu beef producer and seller adds this as being common to agriculture in general: "in agriculture you never count your time".

agricultural policy intended for this ? To what extent is this model desirable for farmers? Can one imagine that the new CAP will respond to this issue as it intends to remunerate farmers in terms of working units?

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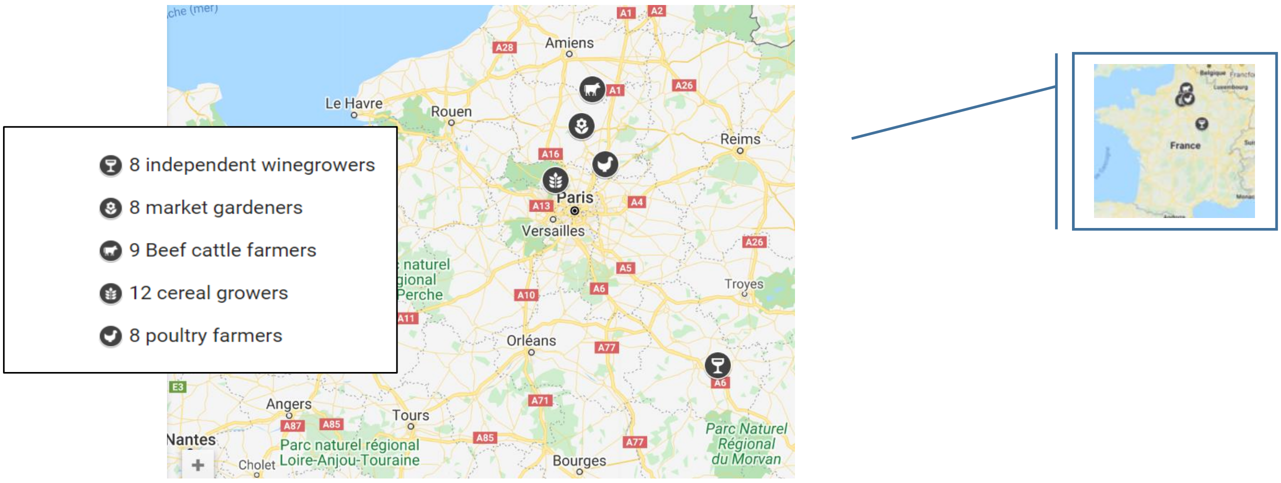
Annex 1. Details on the farmers selected for the qualitative analysis

Table 1. Typology of cereal growers interviewed

Type of farmers	Name	Location (department number) and farm size (ha)	Off and on-farm transformation	Direct selling
Cereal growers	Denis	Val d'Oise (95) 330 ha	Barley and wheat transformed into flour with a stone mill developed in the farm since 2013.	Direct selling and vending machine of flour-barley (stone mill in farm since 2013). Also sells in an AMAP 4 times a year.
	Karl	Val d'Oise (95) 280 ha out of which 15 ha are used for the transformation of wheat and rape-seed and sunflower for the oil.	Oil-mill was set up in 2005 (rape-seed and sunflower). Processing of wheat into flour in their stone mill since 2008. 10% of the production of wheat is transformed on the farm, the rest is sold to a cooperative. 20 tons of wheat is grinded on the farm per year.	Direct selling on the farm for 30% of the flour (the rest is sold to dealers) and for all the oil.
	Diane	Somme (80) 150 ha out of which 60 ha of wheat (sustainable agriculture qualification)	Soft wheat is grinded on the farm since 2016. 3 ha of wheat are grinded (representing 10 tons of flour) every year.	The farm sells biscuit mixes (madeleines, cookies and crackers). Online sales are starting to develop (farmer delivers due to high postal costs)
	Ted	Loiret (45) 135 ha	30 tons of durum and soft wheat (representing 10% of the wheat production) is transformed into flour in the stone mill since 2016	Resellers, markets
	Robert	Loir-et-Cher (41) 164 ha	25% of wheat produced is transformed into flour (stone mill) and fresh pasta (40 tons/year)	Out-of-home catering, resellers (on other farms and farm stores). A certain percentage is sold to supermarkets
	Josephine	Indre-et-Loire (37) 110 ha	Out of 300 tons of wheat produced, 12 tons of wheat are transformed into flour (stone mill).	Flour and sweet and savoury cake mixes are sold on farm stores and on other farms (40 different outlets)
	Celia and Patrick	Pas-de-Calais (62) 68 ha	6 ha of soft wheat are used for heating (representing 4.5 tons/year of wheat grains) cushions since 2008. A seamstress sows the fabric bags.	Resellers (shops, consignment sales). They count 60 outlets in the North of France.
	Brad	Nord (59) 30 ha	15 tons of barley is used to produce 30 000 litres of beer a year on the farm brewery (representing 10% of barley production). Beer production started in 2007. 8 tons of durum are	Resellers (farm stores)

			transformed on the farm into wheat and then transformed into pasta since 2019.	
	Sebastien	Oise (60) 300 ha	Out of 40 ha of barley, 3 tons is used to produce beer on the farm brewery (8000 l/year). The first beer was sold in 2018. The farm also has a malting plant. The farmer sells 50 to 100 kg/month.	Sells on the farm, in bars and on a gardening market. Online sales concern especially malt (50 to 100 kg/month).
	Xavier	Yvelines (78) 160 ha	40% of the wheat is transformed into flour (out of a total of 88 ha) and baked into bread since 2010.	Bread is sold in supermarkets, local outlets and three shops owned by the farmer's two sons.
	Ernest	Oise (60) 16 ha	4.5 ha of wheat are transformed on the farm into flour. The flour (12 tons) is then transformed into sough dough bread (12 tons/year). The farmer needs to transform wheat coming from other farms.	Sells on the farm, in AMAP, and to a dealer (farm sales)
	Louis	Oise (60) 220 ha	No transformation or processing on the farm. Out of 96 ha of wheat, 30 ha are transformed in a local flour mill.	Sells wheat directly to the local flour mill.

Map 1. Location of farmers interviewed



Source: Map elaborated by S. Lupton based on students' data, and using ®GoogleMyMaps

DEFINING PATHWAYS OF TRANSITION TOWARDS A DIVERSIFIED MILK VALORIZATION: WHAT THE HISTORICAL EVOLUTION OF WALLOON DAIRY COOPERATIVES TELLS US

Véronique De Herde[a], Yves Segers[b], Kevin Marechal[c], Philippe V. Baret[d]

[a] Université catholique de Louvain, Earth and Life Institute, Belgium
[b] Katholieke Universiteit Leuven, Belgium
[c] Université de Liège – Gembloux Agro-Bio tech, Unité d'Économie et Développement Rural, Belgium
[d] Université cahtolique de Louvain, Earth and Life Institute, Belgium

Abstract: Dairy cooperatives in the Walloon region do not valorize milk on a diversified pattern of added-value products despite of the agro-geographic characteristics of the region holding potential for it. As the valorization of milk is dependent on the immobility of investments and strategical choices made in the past, we decided to explore the historical background of the present situation. By clarifying the past context and the actions taken by dairy cooperatives in this context, our objective is to: 1) enrich the understanding of the present situation by clarifying which contextual, structural and agent-related roots led to the present situation 2) reveal patterns of agency specific to the Walloon dairy sector that might hold significance in terms of future transitions.

We conducted a historical analysis based on the exploration of archival material, oral sources, and published sources. We contextualized the evolution of dairy cooperatives as from the end of the Second World War up to the first decennia of 2000. That timespan saw the evolutions of milk transformation technology, market configuration, and public policies determine the development of dairies until today.

Our results reveal that the Walloon dairy cooperatives followed an orientation mainly focused on the industrial production of milk powder and butter in response to the guaranteed market outcomes allowed by the Common Agricultural Policy as from the middle of the sixties. The technological investments put the cooperatives in a logic of international competitiveness based on the ability to rationalize the costs and to use the industrial tools to their maximal capacity. The structural characteristics of milk production (density, seasonality, farm-use of the milk) hindered the economic sustainability of this model in the Walloon region. The lack of coordination between dairies in a non-homogeneous political landscape and the inability to define merging strategies exempt of particular interests prevented the development of a concerted strategy to invest successfully in other pathways of milk valorization. In a continuous context of growing International competition on the markets, the price paid to the farmers acted moreover against the capitalization necessary to sustain pathways of higher added-value dairy productions. We point out the tension between the function of farmer as both a *milk deliverer* and a *cooperator* as a source of difficulties to implement pathways of transition from an industrial model of milk valorization.

INTERACTIONS BETWEEN AGRICULTURAL VALUE CHAINS AT LOCAL LEVEL: A METABOLIC APPROACH

Myriam Grillot[a], Sophie Madelrieux[a], Julie Fleuet[b], Jean-François Ruault[a], Pauline Marty[b], Philippe Lescoat[c]

[a] UGA, Irtsea (France)
[b] UTT (France)
[c] AgroParisTech (France)

Abstract: Main resource for human and animal nutrition, agricultural biomass has also high potential uses as substitute for non-renewable resources in other sectors (construction, chemistry, energy, etc.). It plays an important role towards the energetic transition. In that regard, public institutions, particularly at local level, highly support new biomass uses for food and non-food uses, for products (e.g. grains, livestock) and co-products (e.g. straw, manure), leading to value chain reorganizations and/or creations. To prevent from de-structuring the other existing value chains, or from escaping local energetic, environmental or socio-economic issues, it seems important to understand the interactions between value chains in place. For that aim, the framework of metabolism seems particularly relevant. It allows an analysis of the flows of materials and energy occurring between nature and society, between different societies, and within societies. Interactions between value chains can be characterized by material flows and an analysis of actors which produce or use agricultural products and co-products. However, due to value chain specialties, the complexity of actor networks and highly diverse localities, these evaluations are difficult to undertake at local scales.

Our goal here is to present and discuss an approach to account for interaction within and between agricultural value chains, based on a representation of material metabolism coupled with an analysis of actors' networks. First, we build a theoretical metabolism, based on public databases to: i) inform on potential agricultural products and coproducts, ii) gather general information on local actors. Second, we lead a survey to consolidate this metabolism from the actual flows and develop a reading grid of actors' networks based on the forms of: i) circulation of material flows between actors; ii) organization and coordination of this circulation of material flows between actors; iii) synergies, dependencies and competitions between actors around these material flows. The main challenge is to structure these interactions in a global representation of the local agricultural metabolism.

We show an application of the method on two French localities that are contrasted in terms of agriculture in: i) the North of the Aube department, an area specialized in large field crops; ii) the Vallée de la Drôme, farm fields are four times smaller and the agriculture is more diversified with different types of crops and livestock systems.

This method can be used with local partners as a reflexive tool on agriculture and value chains and as a starting point for foresight studies.

A PARTICIPATORY PROSPECTIVE APPROACH FAILS TO IGNITE DEBATE ON THE FUTURE OF THE LIVESTOCK SECTOR IN BELGIUM

Antier C. [a], Riera A. [b], Baret P. V. [c]

[a] UCLouvain, Belgium

Abstract

Livestock systems are challenged because of their environmental impacts and in terms of animal welfare. A now classic vision of the transition of the agricultural sector is the substitution of conventional industrial systems by ecological or organic production systems. However, the benefits, difficulties and risks of such a massive substitution are not always evaluated and rationally discussed among actors.

We developed scenarios towards 2050 for the livestock sector in Belgium. The objective was to provide actors with a shared framework for discussing transition horizons and conditions and challenges for entering transition pathways. The study provided an analysis of the current diversity of production systems in each livestock sector. Three scenarios were then described: a. a business-as-usual scenario; b. a scenario based on extensive systems and relying on national cereals production for livestock feeding; and c. a scenario exclusively based on organic systems and feed from byproducts. This research was funded by an environmental NGO. While the most alternative scenario (c) was chosen in compliance with the NGO's guidelines, the study also offered a reference scenario (a) and an intermediary scenario (b). The consequences of each scenario were assessed in terms of environmental aspects, production, export capacities and required changes in food habits. The study was rolled out with a participatory process: actors contributed to the data collection and then had the opportunity to collectively discuss the scenarios and their consequences. A peer-review was implemented in order to strengthen the reliability of the results. Finally, a public presentation of the study was organized and gathered about sixty participants.

The responses of farmers' unions to the release of this study can be analyzed and provide insights on the understanding of such prospective approaches by actors. Several aspects were identified as critical for ensuring acceptance of the study as a relevant framework: 1. proactively offering transparency on the data and the process; 2. maintaining a clear separation between the NGO's position and the research work; 3. participatory and iterative data collection ensuring a fine-tuned consistency with local context, and 4. having several scenarios presented (not a normative approach based on a single proposition). In spite of those aspects, farmers' unions reactions to the scenarios publication were mostly defensive and focused on supporting the current situation. This questions the possibility of building-up long-term environmental objectives and related policies and operational strategies. In addition, feedbacks were different in the two regions of Belgium, corresponding to two visions of the livestock sector challenging the development of a shared vision at the national level.

Introduction

At the worldwide scale, the livestock sector has been massively growing over the last fifty years. From 1970 to 2017, milk production almost doubled, from 359 million tons to 675 million tons. Cattle meat went from 38 million tons to 66 million tons, while eggs production grew from 19 million tons to 80 million tons, chicken meat from 13 million tons to 109 million tons and pig meat from 36 million tons to 120 million tons (FAO statistics). Meanwhile, the center of gravity of livestock production was moving South, with a few developing countries in Asia, Africa and South America emerging as powerful new players on the global scene. While a large part of the worldwide animal-based production was located in Europe in 1970 (43% of the egg production, 37% of cattle meat production, 37% of chicken meat production and 50% of pig meat production), in 2017, Europe accounted for only 14% of worldwide eggs production, 16% of cattle meat production, 17% of chicken meat production and 24% of pig meat production.

This growth is not inconsequential and the livestock sector has been strongly challenged regarding its environmental impacts. International reports such as FAO's *Livestock's Long Shadow* (Steinfield et al. 2006), which titled « Livestock as a major player in global environmental issues », have highlighted the significant importance of livestock activities in greenhouse gas (GHG) emissions, water depletion and pollution, loss of biodiversity and unsustainable land use. In particular, the report evaluated that livestock are responsible for 18% of greenhouse gas emissions[73]. In a context in which IPCC reports call for limiting emissions[74] and FAO states that « this sector growth needs to be accommodated in a context of finite natural resources, contribute to livelihoods and long-term food security, and respond to climate change » (FAO, n.d.)., it is of concern that livestock production – and GHG emissions – continues its rapid growth. In EU27, the contribution of livestock to GHG emissions accounts for between 12% and 17 % of the region’s GHG emissions (Bellarby et al. 2012).

What are the options to ensure that the livestock sector is, at the worldwide scale, sustainable? There are two parallel approaches to tackle this challenge, which may not have yet been stated clearly enough in international and scientific arenas. The first one is the quantitative question: *how much* livestock production can be maintained under planet's environmental boundaries? The second one is the qualitative approach: *how* to produce sustainably, with which types of livestock systems that are respectful of the environment? Finally, a third question should be asked: is it possible to implement those quantitative and qualitative strategies, that is: can scientific recommendations regarding *how much* and *how* to produce sustainably be endorsed by public policies institutions at the international, regional and national levels and implemented by private actors of the food chain?

This international context reflects in different ways across countries. In Belgium, meat topics have been quite on the agenda in the medias. However, a complete debate taking into account all the challenges related to this question, which could lead to the establishment of a consensus and concerted political decisions, has not yet been conducted. In this context, and with funding from an environmental NGO, we developed a prospective study with three scenarios towards 2050 for the livestock sector. The central objective of this study is to provide actors with a shared framework for discussing transition horizons and conditions for entering transition pathways.

In this article, we present the participatory approach that was mobilized along the elaboration of the scenarios, and analyze the responses of farmers' union to the scenarios publication.

Context: the livestock sector in Belgium, its environmental aspects and farmer’s unions

Livestock productions

Belgium is a small player in the worldwide livestock sector: it provides less than 1% of the eggs, cattle meat, chicken meat and pig meat (FAO stats 2017). However, at the national level, the presence of the livestock sector is noteworthy as the country's production largely overpasses consumption levels, a large share of the production being exported. Self-sufficiency ratios are 109% in the eggs production (i.e. the national production level reaches 109% of the apparent consumption), 135% in the milk production, 158% in the bovine and poultry meat, and 261% in the pork production sector. Belgium has two main agricultural regions: Flanders and Wallonia. Poultry and pigs' livestock activities are mainly located in Flanders: respectively 94%, 84% and 85% of pigs’ population, broilers and laying hens are located in that region. Dairy and bovine cattle raising are more spread across the two regions of Belgium: Wallonia hosts 61% of suckler cows and 40% of dairy cows while Flanders hosts 39% of suckler cows and 60% of

[73] A more recent study revised the estimate of anthropogenic greenhouse gas emissions due to livestock to 14.5% (Gerber et al. 2013).

[74] « With clear benefits to people and natural ecosystems, limiting global warming to 1.5°C compared to 2°C could go hand in hand with ensuring a more sustainable and equitable society » (IPCC 2018).

dairy cows. Livestock systems tend to be more intensive in Flanders comparatively to Wallonia[75] (Riera, Antier, and Baret 2018) (Table 1)..

Table 1: Livestock populations, production and self-sufficiency ratio of meat products in 2015 in Belgium.

	Livestock population	Share in Flanders	Share in Wallonia	Main product	Production	Net consumption [b]	Self-sufficiency ratio [c]
	in number of animals	%	%		Tons of product [a]	Tons of product [a]	%
Pigs	6,364,164	94%	6%	Pork	1,140,326	437,632	261%
Broilers	23,838,182	84%	16%	Poultry meat	369,590	233,832	158%
Laying hens	8,109,466	85%	15%	Eggs	165,269	151,116	109%
Suckler cows	393,595	39%	61%	Bovine meat	261,639	166,083	158%
Dairy cows	507,390	60%	40%	Milk	1,275,496	943,162	135%

Notes:

[a] For bovine, pork and poultry meat, values are expressed in tons of carcass weight. For eggs, data is from 2013 (last available data) and values are in tons of eggs and are estimated from number of eggs, assuming that one egg weights 60g. Finally, for milk, data is from 2012 (last available data) and values are in tons of fresh liquid dairy products.

[b] Net = Production + Imports – Exports and can be associated with apparent consumption.

[c] self-sufficiency ratio = Prod/Net, which gives an indication on how much the national production contributes to the national consumption.

Source: (Riera, Antier, and Baret 2018).

Environmental aspects: GHG emissions

The degree of environmental impact of livestock systems was assessed through four indicators: emission of greenhouse gases, nitrogen emissions, biodiversity score[76], pesticides uses for feed crops

[75] For example, in the eggs production sector, 91% of laying hens are in more intensive in-cage and indoor systems and only 9% of laying hens are in more extensive free-range and organic systems, while in Wallonia, 68% of laying hens are in more intensive in-cage and indoor systems and only 32% of laying hens are in more extensive free-range and organic systems.

[76] In order to characterize the biodiversity impacts of each system, the methodology developed by De Schryver et al. (2010) was used. The method is based on the impact of feed ingredients on biodiversity: a characterization factor (CF) which expresses the ecosystem damages of certain land-uses and agricultural areas, is attributed to each feed ingredient. The CF depends on land uses (arable land and grassland) and intensiveness of agricultural practices (organic vs. intensive). The indicator also varies with the duration of the crop and the occupied area (see step 1 below). The impact of each feed ingredient is then aggregated to determine the overall Damage Score (DS)

and pastures. Those indicators cover three of the twelve midpoint impact categories[77] identified in Life Cycle Assessments (LCA) applied to livestock products (McLelland et al. 2018)[78]. In addition, a qualitative assessment of livestock systems in terms of animal welfare was provided. In this article, we focus on greenhouse gases emissions. and biodiversity score.

Overall, annual GHG emissions due to the Belgian livestock sector were estimated being 13,850 kilotons of CO2e in 2015[79] (Riera, Antier, and Baret 2018). Those emissions come from feed (54%), enteric fermentation (32%) and manure management (15%). The bovine sector is responsible for 57% of total livestock sector's GHG emissions (with 34% from the dairy sector and 23% from the bovine meat sector), while the porcine sector accounts for 34% of livestock sector's GHG emissions, and broiler and laying hens sectors only 10% together. In Belgium's GHG national inventory, emissions attributed to the livestock sector are only enteric fermentation and manure management, that is 7,540 kilotons CO_2e, 7% of national emissions.

The Flemish Climate Policy Plan plans to the livestock sector a further reduction of 26% by 2030 compared to 2005 emissions (Vlaamse overheid 2018), while in Wallonia (the other region of Belgium), no specific objective was so far announced in the draft regional climate policy plan (Agence wallonne de l'Air et du Climat 2018).

The study showed that in each livestock sector, GHG emissions varies from one production system to another. As an example, in the pork production sector, four production systems were identified (Table 2), and it was estimated that the emissions are 3.16 kg of CO_2e per kg of live weight obtained in conventional systems, while it was 3.21 kg of CO_2e in differentiated systems[80] and 3.76 kg of CO_2e in organic systems.

Table 2. Characterization of production systems in the pork sector in Belgium.

	Conventional	Certified (Certus)	Differentiated	Organic
Final live weight (kg)	110	110	120	120
Feed consumption (kg feed/kg live wieght)	2,7	2,7	3,3	3,3

associated to a certain production system (step 2). The higher the Damage Score, the higher the impact on biodiversity.

77 In LCA, a midpoint category describes a proximate impact along the environmental chain that can be measured before the end- point impact is realized (e.g., GHG emissions are a midpoint indicator for average global temperature changes) (Jolliet et al., 2003).

78 McLelland et al. completed a systematic review of the livestock LCA literature to better understand the impact categories included and the progress made towards more comprehensive LCAs. The authors' search of publications between 2000 and 2016 identified 173 relevant peer-reviewed papers and then categorized midpoint environmental impacts into 12 categories based on Jolliet et al. (2004). The twelve categories are: acidification; biodiversity; climate change (or global warming potential); ecotoxicity; eutrophication; human toxicity; ionizing radiation; land use or land occupation; ozone depletion; particulate matter; photochemical ozone formation or photo-oxidant formation; and resource depletion (including biotic and abiotic resources; e.g., fossil fuel, electricity, water, etc.)

79 This figure is obtained without taking into account possible carbon sequestration in pastures due to high data uncertainty.

80 Differentiated systems differs from conventional systems as they guarantee specific raising conditions (non-GMO feed, specific breed, animal welfare considerations, etc.)

Use of phytopharmaceutical products	Yes	Yes	Yes	No
GHG emissions (kg CO_2e/kg live weight)	3,16	3,16	3,21	3,76
Share (% of slaughters)	73%	23%	4%	<1%
Total GHG emissions (kt CO_2e/year)	4,498		201	6

Source: (Riera, Antier, and Baret 2018).

Farmers' unions in Belgium

There are three main farmers' unions in Belgium. Boerenbond and FWA (Fédération wallonne de l'agriculture) are the main farmers' union, respectively in Flanders and in Wallonia. Boerenbond and FWA generally defend positions that can be classified under the conventional agriculture paradigm and are members of COPA-COGECA[81]. FUGEA is a smaller farmers' union located in Wallonia, which defines itself as *a peasant movement that develops and supports agricultural policies in favor of a multifunctional sustainable agriculture [taking into account the aspects of] rural employment, respect of the environment, quality of the products and the satisfaction of the consumers*.

Methodology: scenarios as an intermediary tool in a participatory approach

Participatory approach

The study was rolled out with a participatory approach involving the diversity of livestock sector's actors: farmers' unions, representative of upstream (feed suppliers) and downstream industries (slaughterhouses, commercial intermediaries). Actors were involved similarly to the method presented in (Antier, Petel, and Baret 2018) (Figure 32). First, actors contributed to the data collection through individual semi-directed interviews for the characterization of the current situation. Here, the method relies on a specific participatory process: the 'informed participatory research' (IPR) approach developed by (Van Damme, Dumont, and Baret 2016). The IPR approach combines the classic elements of participatory research and a specific, comprehensive and multi-dimensional assessment of the diversity of farming systems that is discussed with actors in an iterative process. Second, actors had the opportunity to collectively discuss the scenarios and their consequences. Third, a peer-review was implemented in order to strengthen the reliability of the results. Finally, a public presentation of the study was organized and gathered about sixty participants. The final presentation of the study was followed by a significant number of press articles.

[81] COPA is the Committee of Professional Agricultural Organisations, and COGECA is the General Committee for Agricultural Cooperation in the European Union.

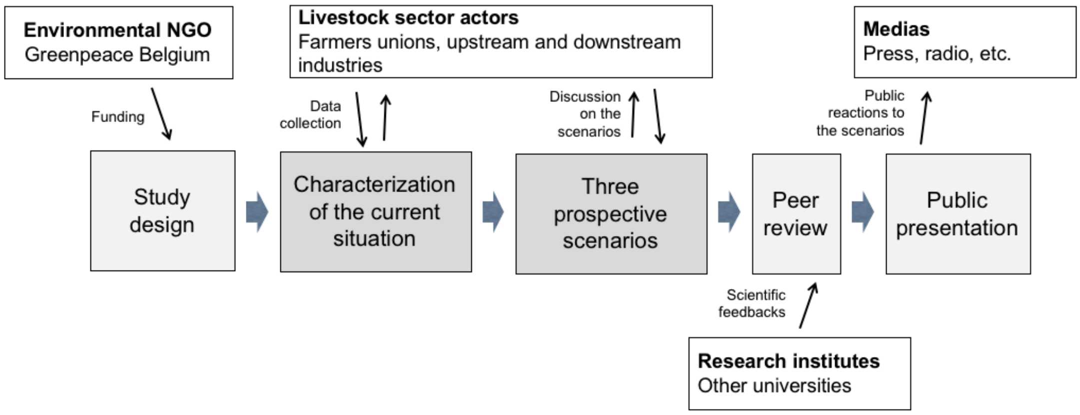


Figure 32. Steps of the study and interaction with actors along the participatory process were different depending on actors.

Three scenarios: a tool for fostering discussion on the sector's productive orientation

« Given the unsustainability of the food system, and the uncertainty of how it may evolve, scenario analysis can be a useful tool for imagining plausible futures as an aid to unlocking business-as-usual thinking » (Benton 2019). Prospective approaches can help to build visions of desirable futures, to develop collective strategies and highlight relevant actions and, consequently, to improve the quality of the decisions to be made (Destatte and Durance 2009).

The authors of *Prospective et Société. Problèmes de Méthodes, Thèmes de Recherche* distinguishes three stages of the prospective approach: a. the **analytical** phase, based on the data and facts collection and the analysis of a current situation; b. the time for identifying "possible futures" (**exploratory** phase); and c. the confrontation of possible futures with the desirable choices, according to an explicit system of values, that then allow to return to the present in order to redefine it according to the desired future (**normative** phase) (Datar 1972).

In our case, an **analytical** phase was implemented through a series of key facts about the livestock sector in Belgium and the inventory of existing livestock systems. The study provides an analysis of the current diversity of production systems, highlighted through a typology of production systems within each of the five main livestock sectors (poultry meat, eggs, pork, dairy and bovine meat production).

Three scenarios at the national level were then described (**exploratory** phase): a. a business-as-usual scenario; b. a scenario based on extensive systems and relying on national cereals production; and c. a scenario based exclusively on organic systems and feed from byproducts. Each scenario implies choices in terms of: a. the respective importance of each sector (in number of animals and in production volume); b. the livestock systems themselves (from the current diversity of systems to a focus on extensive and organic systems); and c. practices (type of feed, etc.) (Table 3).

Finally, the consequences of each scenario were assessed in terms of environmental impacts (through related indicators), production volumes, export capacities and required changes in food habits (Table 4). The business as usual scenario shows no radical change in the livestock population, and the volume of animal based products remain similar. Self-sufficiency ratio is 228%, exports remain a major strategy for the livestock sector. Organic production grows but remain very minor. GHG emissions could decrease of -13%, mainly due to technical optimization. The conditions of transition 1 scenario (T1) listed above implies a significant decrease in livestock populations. As a consequence, meat production would significantly decrease (296 kt vs 740 kt in 2015), leaving no export capacity. The national production would cover national consumption if food diets evolve towards less meat, slightly more than accordingly to current trends. GHG emissions would be halved due to decrease in livestock population and technical optimization. In scenario T2, the conditions set implies an even stronger decrease in livestock populations. Meat production would also strongly decrease (125 kt vs 740 kt in 2015), leaving no export capacity and covering national demand only if food diets radically change (27 g of meat vs 87 g meat/cap/day in 2015). GHG emissions would be more than halved (-58%) due to decrease in livestock population and technical optimization.

The comparison of scenarios shows that:

the reduction of GHGs that can be obtained through technical optimization is limited to -13% (BAU scenario). More ambitious targets of GHG emissions reduction would imply a reduction of the herds (T1 and T2 scenarios);

the livestock systems that are the most efficient on one parameter (GHG per unit produced) are the least efficient on other parameters (biodiversity, pesticides, animal welfare) (the results are provided as an example in the pork sector in Table 2).

It is possible to feed the Belgian population by significantly reducing the number of herds. Scenario T2 requires a real shift in consumption patterns while scenario T1 is very close to food diets trends.

Table 3: Description of the scenarios.

	Business-as-usual scenario	Transition 1: the intermediary scenario	Transition 2: a radical shift
Production systems in the scenarios	The scenario continues the trends from the past 10 years	organic and extensive systems	Only organic systems
Feed		Cereals feed: using only national (BE) resources	No cereal feed. Only regional (EU) coproducts for animal feed
Pastures area	427.551 ha (-23% vs 2015)	556.845 ha (no change vs 2015)	556.845 ha (no change vs 2015)
Bovine systems	Dairy Meat	Mixed dairy systems	Mixed dairy systems

Table 4: Consequences of the scenarios.

	Business-as-usual scenario	**Transition 1: the intermediary scenario**	**Transition 2: a radical shift**
Livestock population (in million livestock units)	no major change: - bovine cattle: 0.23 (-26%) - dairy cattle: 0.49 (-4%) - laying hens: 1.38 (+20%) - broilers: 0.11 (+0%) - porcine: 3.61 (+1% vs 2015)	significant decrease: - mixed cattle: 0.61 (-26%) - laying hens: 0.36 (-69%) - broilers: 0.05 (-55%) - porcine: 1.37 (-62%)	very strong decrease: - mixed cattle: 0.69 (-16%) - laying hens: 0.09 (-92%) - broilers: 0.01 (-91%) - porcine: 0.34 (-90%)
Respective importance of each sector	- bovine cattle: 4% - dairy cattle: 8% - laying hens: 24% - broilers: 2%	- mixed cattle: 26% - laying hens: 15% - broilers: 2% - porcine: 30%	- mixed cattle: 61% - laying hens: 8% - broilers: 1% - porcine: 30%

(in % of livestock units)	- porcine: 62%		
Organic production	<6%in each sector	+30%in each sector	+100% in each sector
GHG emissions	-13% vs 2015 mainly due to technical optimization	-48% due to decrease in livestock population + technical optimization	-58% due to decrease in livestock population + technical optimization
Meat production	743 kt similar to 2015	296 kt versus 740 kt in 2015	125kt versus 740 kt in 2015
Meat consumption	70g meat/cap/day versus 87g meat/ cap/day in 2015 (trend)	64g meat/cap/day versus 87g meat/cap/day in 2015	27g meat/cap/day versus 87g meat/cap/day in 2015
Self-sufficiency of meat	228% versus 209% in 2015	100% (no export capacity)	Based on a shift in diets no export capacity

Methodology for analyzing actors' reactions

The responses of actors at the regional and national level to the release of this study can be analyzed and provide insights on the understanding and conditions for the appropriation of such prospective approaches by actors. As shown by (Bengtsson and Tillmann 2004), it is useful to analyze how actors define, and relate to, problems and interpret the risks and benefits of different options in order to understand the nature of a controversy and what need to be address for allowing progress in this controversy.

In this perspective, the press release from each of the three farmers' unions was collected[82]. Arguments were listed in each publication and classified into three categories: arguments challenging the relevance of the study (R), arguments focusing on the current situation and its technical and economic constraints (C) and arguments about possible futures (F) discussing scenarios with their advantages and risks.

Farmers' unions responses to the scenarios

There were 24 arguments across farmers' union press releases, mainly arguments challenging the relevance of the study (9 arguments) and discussing the current situation (13 arguments) while only two arguments were about the future (

Table 5).

Table 5: Some press releases and types of arguments

Code	Types of arguments	Number of arguments in farmers' unions press releases
R	Challenging the relevance of the study	43% (9 arguments)

[82] Rapport Greenpeace- la Fédération Wallonne de l'Agriculture réagit ! www.fwa.be/elevage/rapport-greenpeace-la-federation-wallonne-de-lagriculture-reagit-2

Le rapport de Greenpeace, opportunité ou massacre ? fugea.be/05-02-2019-le-rapport-de-greenpeace-opportunite-ou-massacre/

C	Technical and economic aspects about the current situation	48% (13 arguments)
F	Scenarios and possibities for the future	10% (2 arguments)

Overall, farmers' unions (in both regions) interpreted the study's purpose as willing to denigrate farmers' activities (a purpose stated as « agribashing » by Fwa) and challenged the relevance of reducing meat production. Meanwhile, their press releases included very few comments on the comparison of the three scenarios. Similarly, typologies of production systems, which were the keystone for describing the current situation of livestock sectors and for the elaboration of the scenarios, were not mentioned in their press releases. Arguments are detailed below.

Arguments aimed at challenging the relevance of the study

The first argument (present in each of the farmers' unions press release) was that livestock only accounts for a small share of national GHG emissions, and that efforts should therefore rather be implemented in other sectors. Boerenbond underlines that « *livestock farming accounts for only a limited share [of climate impacts]. Today, livestock farming is responsible for barely 7% of greenhouse gas emissions in Belgium. This puts it in fifth place, after mobility, energy, households and industry* ». FWA reminds that the livestock in Wallonia accounts for « *only 4% of Belgium GHG emissions* ». Boerenbond then concludes that « *a reduction in livestock will only lead to a minimal reduction in total emissions. The reduction of our livestock is therefore not the solution for the climate problem!* ».

The second argument provided for challenging the prospective study relevance was the significant efforts already accomplished by the agriculture and livestock sector regarding environmental externalities. Boerenbond estimates that « *in the past 30 years, the sector has already achieved a 20% reduction [in GHG emissions]* »[83]. FWA also stated that « *our agriculture sector, aware of the importance of increasing its sustainability, has taken into account the needed changes in its farming practices* ». FUGEA considers that « *solutions already exist and are being implemented in our farming systems* ».

Finally, there were arguments against the study as farmers' unions perceived it as an attack towards farmers. Boerenbond considered that the study was seeking « *stigmatizing our Flemish livestock farmers* » while FUGEA considers that « *it is damaging to Walloon breeders to be included in a national inventory* » given that « *agricultural realities [between the two regions] are not comparable* ».

Arguments based on economic or technical aspects in the current situation

First, there were four arguments about the current livestock' sector economic context. Firstly, farmers' union argued that the integration of their sector into international trade rules and competition limit the relevance of prospective approaches at a national level. Boerenbond reminded that « *meat imports [...] cannot be prevented* » while FUGEA regretted that the study « *presents Belgium as an island, whose only mission is to feed its population* ». Second, the unions highlighted the economic challenges already faced by the farmers. Boerenbond proposes that a priority should be given to « *stop the outflow from the sector* » [84] while FWA asked *« to support the farming sector and to increase farmers' revenues* ». Third, it was underlined that consumers' food diets evolution may not go along with the transition scenarios. Boerenbond challenged: « *The study assumes - also somewhat naively - that Belgian*

[83] This decline is, in fact, largely related to the evolution of livestock populations. At the Belgium level, between 1990 and 2018, the cattle herd decreased by 26% (Etat de l'Environnement wallon 2019). Emissions have fallen due to a decrease in emissions from enteric fermentation and decrease in the amount of nitrogen excreted on grazing land (Commission Nationale Climat, n.d.).

[84]

consumers will not consume more than 23 grams of meat per day, spontaneously consume only Belgian meat from the (more expensive) organic chain and ignore other (foreign) meat ». Finally, the orientation of subsidies towards sustainable practices was underlined as FWA reminded « the current CAP already includes 30% of the aid budget for greening approaches », suggesting that no further economic support could be obtained for undertaking a more significant or rapid transition pathway.

There were also two arguments on current livestock systems themselves. Farmers' union tented to underline the performance and the positive aspects of current systems. FWA talked about « *family farms* » which are « *far from the industrial farms described by Greenpeace* ». Boerenbond reminded that « *conventional farming systems score better in terms of climate than extensive farming systems* ».

However, none of the actors explicitely talked about the typologies of production systems. Specifically, discussions on environmental aspects were focused on GHG emissions while the other aspects (nitrogen emissions, biodiversity score, use of pesticides) were not mentioned, and the relative impacts of intensive and extensive/organic systems in terms of GHG emissions and biodiversity impact were little discussed.

Arguments related to scenarios and possibities for the future

Across the press releases, there were two arguments – provided by Boerenbond only – related to the scenarios themselves. The first argument is that a business-as-usual scenario with stronger reduction in GHG emissions can be achieved: *« The Flemish Climate Policy Plan imposes a further reduction of 26% by 2030. Ambitious, but the sector is willing to commit to this. However, this reduction does not necessarily - contrary to what Greenpeace proposes - lead to a reduction in livestock, but can also be achieved through technology and innovation (adapted feed ration, management, etc.) ».* However, no strategies and technical innovation were explicitely presented as solutions for reaching this ambitious objective. The second argument is that socio-economic aspects should be in first line of scenarios' design, instead of engaging into a reduction of the livestock populations. Boerenbond regretted that *« the socio-economic impact [of the possible scenarios] is completely disregarded »* while *« declining the stock of livestock [is seen] as a miracle solution ».*

Discussion: factors that limited the emergence of a debate on the scenarios

One of the objective of such a prospective approach and participatory process is to facilitate the emergence of a debate based on relevant arguments.

Several aspects were identified as critical for ensuring acceptance of the study as a relevant framework: 1. proactively offering transparency on the data and the process[85]; 2. maintaining a clear separation between the funding body (an environmental NGO) political position and the research work; 3. participatory and iterative data collection ensuring a fine-tuned consistency with local context, and 4. having several scenarios presented (not a normative approach based on a single proposition).

In spite of those aspects, when analyzing farmers' unions responses to the scenarios' publication, it appears that their arguments were mostly defensive of the current situation, as the analysis of their press releases show: 9 arguments challenging the relevance of the study, 13 arguments discussing the current situation and only two arguments were about the future (see above). This questions the possibility of building-up and implementing shared long-term environmental objectives at the national

[85] The transparency measures included online communication, individual meetings on demand and actors group discussion in which information was provided regarding funding sources, study objectives and process, methodology and limits.

level. We discuss below some factors that contributed to limit the emergence of a debate on the scenarios themselves.

A specific context: an object with a high symbolic value already under crisis

This prospective study was applied to an object (meat and animal-based products in general) that is already under crisis. Different topics are included in this crisis such as the environmental consequences, health issues related to food diets, economic viability of farms, and ethical issues of meat consumption. The question of meat consumption levels and associated ethical and environmental dimensions has been especially high in the media over the last years, with the opposition of vegan principles to farmers' and traditional food culture. In our context, this focus was at the expense of the debate about livestock systems themselves and their respective impacts that the study could have brought up. Indeed, the debate partly moved out of the political arena in which it would have supported the elaboration of policy decisions based on consensus, and shifted to the individual sphere of consumer responsibility. Meat consumption has, in general, a high degree of cultural elaboration (Fischler 1991; Fiddes 1991). The symbolic value of meat in the sector and in the Belgian society in general may have strengthened the difficulty of entering a strategic discussion about the sector and its production levels.

Actors attitude: extreme positions rather than compromise.

The choice of providing typologies of production systems (beyond a simple opposition of conventional vs organic systems, see Table 2) and presenting three scenarios (not only one, or two) was made in order to facilitate the emergence of an educated and open discussion.

However, in spite of the presentation of several scenarios, actors were generally publicly denouncing the study or defending the feasibility of the business-as-usual scenario. While the most alternative scenario was chosen in compliance with the NGO's guidelines, none of the actor talked about the intermediary scenario which could have been seen as a consensus. We link this to the logic of advocacy in which actors are involved, which makes it difficult to incorporate facts and to be involved in a debate based on its real terms.

Difficulty to encompass multi-dimensional scenarios

Most of the arguments in the debate (both from farmers' union and other actors) were focusing on a specific dimension (farms' viability, employment, food accessibility, etc.). They did take into account other dimensions such as environmental aspects only separately from production levels arguments. In addition, entire aspects of the debate, such as the relevance of an increased share of organic production, were entirely missed. This shows a difficulty of the actors to encompass multi-dimensional scenarios, while they focus on defending their interests in the current situation. This may be linked to the fact that, in Belgium, due to education programs design and content, farmers tend to develop a shared vision about farming mainly based on intensification, growth and high investments in equipment (De Herde, Maréchal, and Baret 2019). Consequently, and as "pedagogy underlies all food system change, especially for forming cultural legitimacy of emergent spaces" (Hsu 2019), pedagogy is likely to be a crucial aspects for successfully bringing such prospective, multi-dimensional approach into the public arena.

Although a complete debate on the desirable futures and relevant transition pathways of the livestock sector in Belgium was not directly generated by the study, the extent of the reactions in the media tends to suggest that an agenda effect has still occurred. This is supported by the fact that the scenarios have been regularly mentioned in later debates.

Synthesis: two opposed ideologies

Underlying the above discussion is the question of ideologies. We provide in Table 6 a synthesis of the differences of views identified between the farmers' unions and the funding NGO. This could be further linked to different *agrarian ideologies* (as studied by (Beus and Dunlap 1994)) or different *cognitive framings* (as defined per (Surel 2000)) of the livestock's future controversy across the Belgian society.

Table 6: Compared views of farmers' unions and the environmental NGO who funded the study.

Topic	Farmers' union views	NGO views
The Belgium livestock sector should change, in accordance with worldwide livestock' sustainability challenges	A small country like Belgium has little influence on the worldwide trajectories.	A shrink-and-share approach[86] is needed, for achieving a balanced amount of animal protein among the poorer peoples in the world will inevitably require drastic cuts in the richer sections of societies.
Agriculture functionality	Economic viability first	Multi-dimensional
The livestock sector is responsible for 7% of national GHG emissions.	The livestock sector contribution to national GHG emissions is small.	The livestock sector contribution to national GHG emissions is significant.
Objective for livestock sector GHG emissions reduction	The definition of a GHG reduction objective is not necessary for the livestock sector in Wallonia. There already are objectives defined in Flanders (-26% in 2030).	An ambitious GHG reduction objective should be defined for the livestock sector in Belgium (about -70% in 2050).
Production systems	Current production systems are acceptable	Current production systems are not acceptable in terms of biodiversity impact, pesticides use, animal welfare. Only organic, extensive systems should be maintained on the long term.

Conclusion

The publication of those scenarios on the future of livestock in Belgium offer an interesting experience on the potential of prospective studies as a tool for facilitating the emergence of an educated debate, but also on the importance of differences in cognitive frames that affect an effective debate. In spite of the presentation of several scenarios, farmers' unions were generally publicly denouncing the study or defending the feasibility of the business-as-usual scenario. Although a complete debate on the desirable horizons and relevant transition pathways of the livestock sector in Belgium was not directly generated by the study, the publication of this study led to a cycle of encounters of farmers' unions and the national environmental NGOs. This permits to confront arguments from both sides and to highlight central differences in their worldviews and priorities. In addition, the study allowed to raise key topics for transition pathways (such as the potential of alternative, vegetal proteins in the country; the relevance of choosing which production systems to develop; etc.). Although this article focuses specifically on the responses of farmers' unions, the study was more broadly addressed to actors, including education and

[86] The reduction in the global consumption of meat should be achieved with regional considerations on equity, i.e. a common global objective but differentiated responsibilities (Tirado 2019). In Greenpeace’ s vision, the global consumption of meat should be reduced to 24 kg of meat per capita per year in 2030 (16 kg in 2050) and this should be achieved through a massive reduction in the consumption in the more developed countries and a limited increase in the consumption in the less developed countries (Africa, India).

policy actors. The understanding and appropriation of the scenarios by those actors could be further investigated.

The limits of the scenarios, widely recalled by the farmers' unions, call for a deepening of this kind of prospective study by including the economic consequences (such as the creation of value and the employment) of the scenarios.

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THE ROLE OF RELATIONAL MARKETS AND FARMER AGENCY IN THE PURSUIT OF AGROECOLOGICAL PRINCIPLES AT FLEMISH BEEF FARMS

Tessier, L.[a], Bijttebier, J.[b], Marchand, F.[c], Baret, P. V.[d]

[a] Flanders Research Institute for Agriculture, Fisheries and Food (ILVO), Catholic University of Louvain (UCL), Belgium
[b] Flanders Research Institute for Agriculture, Fisheries and Food (ILVO), Belgium
[c] Flanders Research Institute for Agriculture, Fisheries and Food (ILVO), University of Antwerp (UA), Belgium
[d] Catholic University of Louvain (UCL), Belgium

Abstract

In our exploration of what sustains and limits agroecological practices at beef farms in Flanders, the relevance of alternative food networks as an assisting or even necessary factor in putting agroecological principles into practice became increasingly clear. The question remained, however, whether alternative, market-based arrangements could in any way be scaled up. This led us to analyze how alternative and not so alternative market exchanges were different and connected. In this paper, we navigate through the rich debates within economic sociology on the social structural basis of market exchanges. We identified two challenges: (i) synthesizing the emphasis of Marxian political economy on objective material relations, and the emphasis of actor-centered approaches on cultural rules in one theory of agency; and (ii) creating a single framework of market exchanges that accommodates the varying influences personal relations among actors have on actual market exchanges. We argue that the work of critical realists such as Douglas Porpora on agency, and the heterodox economist William Jackson on relational markets can be instrumental in meeting these two challenges, respectively. In the second part of this paper, we highlight some observations from our interviews with Flemish beef farmers that triggered these critical reflections on existing approaches to market exchanges in agro-food studies. Developed in 2018, this practice-theoretical framework has since then been applied extensively in the context of beef farming in Flanders (cfr. Ph. D. dissertation, 2021), confirming its versatility and explanatory power for studying alternative and not so alternative market based food networks.

Introduction

Alternative food networks (AFN) figure often as exemplary instances of agroecology, as they appear to address agroecology in all its dimensions, including the socio-economic, -cultural, -political (Dumont, Vanloqueren, Stassart, & Baret, 2016). Moreover, the establishment of economic arrangements of more reciprocal nature between local partners have proven to be central to the socioeconomic viability of systems managed along more agroecological lines in numerous case studies (FAO & INRA, 2018). The mere existence of AFN calls into question deterministic analyses of agricultural development, which conclude on political economic or on discursive grounds that the modernization of farming is inevitable (Renting, Marsden, & Banks, 2003). Yet, in doing away with a determinism of “only one thing is possible”, we must be wary of overcompensating, and opening the door to an excessive voluntarism of “anything is possible” (Hart, 1998). While the model of Homo oeconomicus is rightfully dispelled by rural sociologists as a reductionist model of human agency, it’s difficult to explain the overwhelming lack of involvement of most farmers and consumers in AFN, without some reference to an economic structure motivating certain behaviors. Due regard to the structural basis of market exchanges therefore still needs to be given to understand farmer behavior.

The agency of farmers remains the subject of ongoing conceptual and analytical debate in critical agri-food studies. These debates are dominated by political economy and actor-centered approaches (Higgins, 2006). Political economy approaches foreground the fact that most farmers are commodity producers and therefore part of a wider social division of labor in a capitalist society. It therefore starts out by analyzing how and to what degree these social relations of production affect farmers' thinking and actions (Bernstein, 2010). Actor-centered approaches foreground the interpretive moment in all human behavior, i. e. that farmers are not passive recipients of transformative forces, but that they are "active participants who process information and strategize in their dealings with various local actors as well as with outside institutions and personnel"(Higgins, 2006). Both political economic and actor-centered approaches are recognized by rural sociologists, but typically their supposed salience depends on the scale and time-frame under analysis (Lamine, Darnhofer, & Marsden, 2019). The political economic approaches are able to explain the existence of large-scale and enduring trends of global food systems, whereas the actor-centered approaches are much more in tune with the diversity and intricacies of meanings and practices observed in anthropological fieldwork. Connecting the dots between these separate explanations of individual practices, and larger economic or institutional determinants remains, however, a key conceptual challenge within the field of rural sociology (Lamine et al., 2019). In our estimation, closer analysis of market exchange as a practice may serve as a potential linchpin in addressing this challenge, given the interconnecting and pervasive nature of this practice at higher and lower levels of contemporary agri-food systems.

In actor-centered approaches, market exchanges figure as a part of the many instituted practices found within social networks of actors, and they are explained as a more or less path-dependent product of rule-following behavior and negotiation of conventions and expectations among actors. This approach is justified based on the observation that most actual exchanges don't take place under ideal competitive market conditions, i. e. impersonal, voluntary, and uncoordinated trade, but that are in fact embedded within social networks of interpersonal relationships (Granovetter, 1985). This fact renders indispensable an analysis of these networks, in order to explain the characteristics particular of trades. This strategy to re-appropriate market exchange as a subject of sociological inquiry amounts to a whittling away at the market construct, revealing that an ever-greater share of transactions are enacted through interpersonal relationships (Krippner et al., 2004). However, in the relative absence of such personal relations (for example traders using algorithmically automated systems to trade stocks) this approach is unable to explain these trades in purely social terms and therefore to make neoclassical models entirely obsolete.

While actor-centered approaches correctly stress that most market exchanges are embedded in personal relationships, it misses that all market exchanges, no matter how instantaneous, are social in the broader sense of the term in two interconnected ways. First, the mere possibility of exchanging commodities depends on such institutions as property and contract law, and it predisposes actors with certain understandings of themselves and the world so that they accept to exchange under a certain set of social rules and not another. These are conditions perhaps even unthinkable in most of human history, yet they are contained into every market exchange, and do not variably exert their influence on some kinds of markets more than others (Krippner et al., 2004; Tordjman, 2004). Second, and this a crucial insight of Marxian political economy, market exchange cannot be separated from the sphere of material production in a capitalist society, as it is the particular form social relations of production have taken and have to take in a society that is made up mostly out of formally independently acting producers. In the absence of direct social regulation of production (e. g. planning in the factory, the household, within the tribe, or by the state), the working activity of members of a market society is regulated through and only through the exchange of things. It is the circulation of goods on the market, the rise and the fall of their prices that lead to changes in the allocation of the working activity of separate commodity producers, and thus to their entry into certain branches of production or their exit from them. While direct social regulation of production plays its part in contemporary society, influential economic thinkers, as disparate as Marx, Polanyi, Hayek, Schumpeter and Keynes (Richards, 2018) have contended that market dynamics form an autonomous mechanism that dominates social production in capitalist societies. It is easy to dismiss visions of "the Invisible Hand of the Market" or "Laws of Supply and Demand" as illusory reifications of actors parroting neoliberal ideologies and mistaken economic beliefs (e. g. Long, 1997). It is much harder to come to terms with the reality that miraculously enough, a society constituted out of mostly autonomously acting buyers and sellers of products is more or less able to materially and socially reproduce itself without any direct co-ordination (Rubin, 1928).

We can therefore not theorize market exchanges merely in terms of interpersonal relationships among actor-networks identified in a case study, but it must include a theory on how the actions of all buyers and sellers in society structure farmers' behavior, both culturally and materially. In search for such a theory, we came across two publications that were instrumental to overcome two hurdles we identified in our own grappling with the subject. The first challenge is to accommodate the emphasis of Marxian political economy on objective material conditions motivating human behavior, and the emphasis of actor-centered approaches on cultural rules in one theory of agency. We believe that Douglas Porpora's (1993) theorization of agency is very useful to bring the insights of these schools of thought together. The second challenge is to create a single framework of market exchanges that accommodates the influence personal relations among actors may varyingly have on actual occurring exchanges. We believe that the work of heterodox social economist William A. Jackson (2007) is a substantial contribution herein, as he theorized market exchanges of more and less relational nature in social structural terms. Jackson proposes a layered structure of social positions occupied by buyers and sellers determined by personal and impersonal social relations among these positions (figure 1). This is, we would argue, a powerful entry point to explain exchanges that actually take place in agro-food systems.

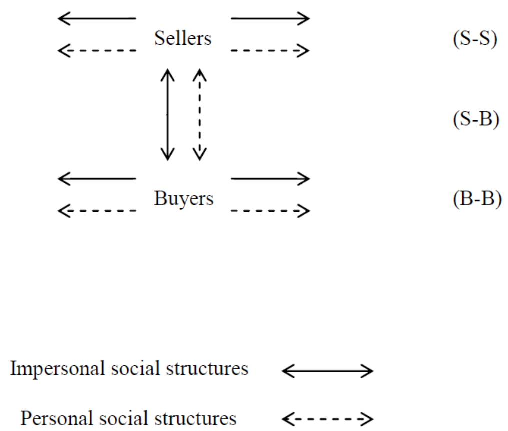

Figure 33. General social structure underlying market exchanges (Jackson, 2007).

Analytical Framework

Synthesizing Social Relations, Cultural Rules and Agency

In an article published in 1993, Porpora observed that there are at least two important traditions within sociology, the first following Marx (or at least a particular strain in Marx's thought), and the second, following Winch and Giddens, that agree that social behavior has to be explained in terms of its context. They disagree, however, on the nature of that context. Whereas Winch and Giddens stressed the cultural context created by constitutive rules, the relevant Marxian tradition emphasizes the material context created by objective social structural relations. Porpora goes on to argue that a more complete context for explaining behavior involves both constitutive rules and material relations, and that this context analytically precedes actor's further self-understanding and behavior. His framework includes three different analytical moments that dialectically influence each other: cultural constitutive rules that establish objective social relations, the social relations themselves, and the situated behavior and self-understanding of actors (figure 2). In this vision, objective social relations arise from the constitutive rules that constitute a group's way of life. For instance, it is the historically specific, shared understandings within a slave society that define who is a slave and who is a slave master, and the expected behaviors that go along with this position. However, although such relations depend on the conscious rule-following behavior of actors, they have an objective existence independent of actors' specific awareness. To go further with the example, whether a specific person understands him- or herself to be a slave, makes no difference at all to that person being in that particular social position. In fact, these relations may remain opaque to their understanding, just as generative mechanisms and processes of the natural world, like gravity or photosynthesis, may remain so. Yet, since this objective social position is necessarily part of the life-world of any subject in this position, it provides the subject reasons to act. According to Porpora, these social positions themselves contain built-in objective interests and provide distinct motives for action insofar as actors are aware of them. A slave may, for instance, realize he or she would do well not to speak ill over his or her master in public, but may also be well advised to seek to overthrow the system of slavery altogether. However, there is no guarantee that a person will become aware of these interests nor act accordingly. In this conception then social relations can motivate and enable certain behaviors, they are therefore socially consequential, and thus are part of a causal explanation of social behavior. Moreover, the social relations generated by the constitutive rules may differentially benefit and empower certain actors, for instance slave-masters vis-à-vis slaves, who are thereby enabled to maintain or change the rules. Objective social relations are therefore a piece of the puzzle in explaining why the rules are what they are.

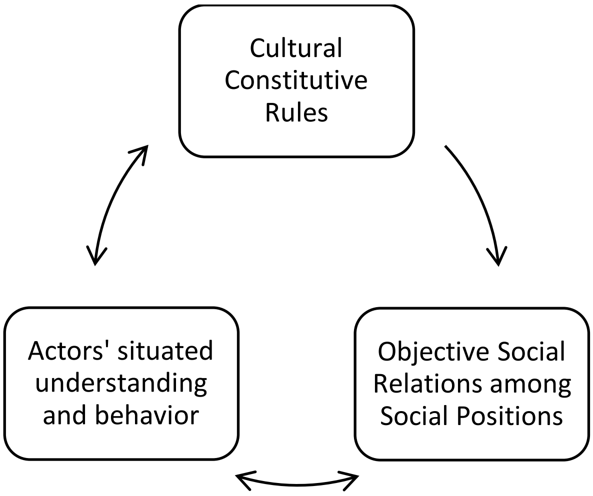

Figure 34 The three analytical moments outlined by Porpora (1993).

Impersonal social relations

In line with Porpora (1993), then, and based on Isaac Rubin's account of Marx's theory of value (Rubin, 1928), but also following Howard Richards' (2018) lead, the underlying structure of competitive market exchanges can be conceived of as a network of objective social relations among actors occupying specific social positions, as they are possessors of different commodities which are exchangeable in principle. While these are social relations, these are curiously enough impersonal, as they are mediated through things and things alone. Simply by virtue of the exchangeability of their commodity, any owner of a commodity stands in relation to other owners. Not only is he or she connected with those entering with him or her into a contract of purchase and sale, but in fact by a thick network of indirect relations, with innumerable other people (for example, with all buyers of the same product, with all producers of the same product, with all the people from whom the producer of the given product buys means of production, and so on), in the final analysis, he or she is connected with all buyers and sellers of society (Rubin, 1928). As also argued by Karl Polanyi (Machado, 2010), these relations have a profoundly dis-embedding influence on local economies, as economic actors are now forced to take into account the working activity of all other members of society, to the extent that it influences the movement of commodity prices on the market (Rubin, 1928).

Of course, the existence of these impersonal social relations, which Richards (2018) refers to as the "basic structure of the market", is predicated upon the constitutive rules of the market such as the institutions of property and contract law, and the general adherence of actors to these rules. The continued reproduction of this system also relies on broader norms and customs which have long been internalized by market participants, given that economic actors don't need to reach for a manual or consult a therapist to know what to do when the prices change. In fact, to most people in our society, these rules appear as the natural way of doing things, and they are accepted and reproduced in every act of exchange. These cultural rules and objective social relations pre-exist the understanding of members of capitalist societies, as they are literally born into a world with such rules and relations. Yet through experience they develop an understanding on how to act upon this reality. While actors are not condemned to specific roles, for instance a rich person may choose to give away his or her fortune, or advocate for the abolishment of private property, they do tend to act in a predictable fashion. An owner of commodity tends to exchange his/her commodity for another commodity, insofar as it is of better use to him/her. And as most buyers figure that it is in their interest to secure a purchase at the lowest possible price, they tend to act accordingly. Indeed, at a micro-level, the existence of such social structure can explain a substantial set of beliefs and actions of members in such a society. Moreover, because commodity owners follow a consistent and predictable pattern of behavior, it also leads to particular tendencies at a macro-social level, for instance, the emergence of a self-correcting price mechanism of over- and underproduction, which, is precisely what various economic thinkers have argued to exist (Richards, 2018). By virtue of these relations, buyers and sellers set in motion through the exchange of commodities, independently from their will or knowledge of this laws regulating social production and consumption. As this systems of social relations does not require economic actors to know much about the world to act effectively in it, it relieves economic actors from directly organizing production in society (Morozov, 2019). Then again, as argued compellingly by Moishe Postone (2017), it constitutes an extremely resilient form of abstract social domination, which subjects people to impersonal and increasingly rationalized, structural imperatives and constraints.

Personal social relations

Actual market exchanges occur under circumstances that diverge from anonymous role playing, as sellers and buyers may be loyal or bound to each other and thus swayed by things other than price. Jackson proposes that such trading behavior is mediated through other social structures too, and he discusses in particular the 'personal social structures' developed through enduring trading, between and among buyers and sellers. Likewise, these structures are objective and of social consequence, but they are a softer form of social structure. As they are constituted by rules negotiated at a lower-level, but also are more intelligible to actors involved, they are more subject to change. The rules that are established at this level include those that Tordjman (2004) refers to as procedural rules, by which exchange is concretely organized. Jackson studies three interactions in particular: between sellers, between buyers and between buyers and sellers, through which market exchanges gain a more personal character. We would, however, also include other actors such as governments and state bureaucracies, sector organizations, and family members, personal friends, and employees, which create particular cultures within social networks e. g. Abolafia, (1998), thus redefining the particular social positions commodity owners find themselves in. As it is through this personal network that commodity owners forms an opinion about what, who and how commodities should be traded, they play a vital role in explaining actual trading behavior. Insofar that these personal relations are endowed with power, these are direct power relations between individuals or between groups of individuals, such as we can find in the patriarchal family, or in tribal or feudal society.

Layering of social structures

By making a distinction between actual events and the mechanisms that generate them, in accordance with a critical realist ontology, we can explain market exchanges in terms of a layered social structure. This social structure exists out of both impersonal and personal social relations among social positions, constituted by two sets of cultural rules at different levels of society. These two sets of relations co-exist and define together objective social positions which motivate, enable and constrain actors' behavior. Following Jackson (2007), a layered approach can accommodate a wide range of competitive and relational trade within a definition of markets that distinguishes them from purely direct reciprocal and redistributive economic arrangements. Based on an analysis of the varying prominence and combinations of these personal and impersonal ties among buyers and sellers, Jackson (2007) demonstrates that a typology of markets can be constructed, which include particular roles actors in these various positions tend to play. However, given the indeterminateness of agency, it remains crucial to study how cultural rules and impersonal and personal relations are reproduced in different contexts.

Grounding the analytical framework: materials and methods

So far, we presented the development of this analytical framework as a product of critical reflections on existing literature. However, these reflections occurred simultaneously with the analysis of semi-structured interviews gathered on 37 Flemish beef farms (Tessier, Bijttebier, Marchand, & Baret, 2018), spurring us to entertain the possible existence of objective personal and impersonal relations underlying the market exchanges referred by the farmers. We therefor return to our own fieldwork to show how these data gave us reason to believe existing frameworks were incomplete. The data include 37 semi-structured interviews with beef farmers in Flanders, who were selected along the range of three axes a priori established (table 1). In 25 cases we spoke with only male identified members of the farm household, in 5 with only female identified, and in 8 cases with both male and female identified members of the household. All farmers were from white ethnic background. The main goal of this data collection was to explore which actions are taken, by what kind of farmers, on what kind of farmers in line or against agroecological principles, and in a further analysis why (Tessier et al., 2018). For the purpose of this paper, we re-read the transcripts, and coded revealing instances where farmers referred to the existence of market forces controlling their lives, chain actors and consumers. However, in the analysis of these parts, we also note the role of personal relations and farmers' agency in creating diverse outcomes.

Table 18 Distribution of cases along the three a priori axes used for purposive sampling: Organic or in transient to Organic or not; Direct Sale of meat or not; Diversified Agricultural Activities, defined here as rearing other livestock species than bovines for sale or growing cash crops (excluding wheat).

Organic?	Direct Sale of Meat?	Diversified Agricultural Activities?	Tot #
Yes	Yes	Yes	10
		No	1
	No	Yes	1
		No	0
No	Yes	Yes	5
		No	3
	No	Yes	14
		No	3

Results and analysis

Whereas the analysis of sets of practices mentioned by individual farmers is still ongoing, we can already foreshadow that the cases are remarkably diverse and distinct along multiple dimensions of farming. This is no coincidence as we aimed at including a wide range of beef production systems in order to explore with this sample the full scope of agroecology on Flemish beef farms. There is, however, a noticeable uniformity in terms of social organization of production, as these farmers strongly depend on markets to socially reproduce: they sell their products of labor in order to buy means of production. Yet this dependence on markets varies on a case-by-case basis. Some farmers acquire goods and services by gift or reciprocal arrangements with neighbors, consumers or nature organizations, or they acquire means of payment through state subsidies, lending or inheritance, or through non-agricultural activities such as wage work, tourism, etc., or they are in part subsistent. These observations show that there remains scope for a diversity of agricultural practices, which tie into a varying ability of farmers to socially reproduce without having to sell their products of labor. Nonetheless, even though these farmers may produce beef very differently, they all rely on market exchange to some degree, revealing they are confronted with a similar objective situation, and in many respects act upon similarly.

Closer analysis shows, however, that the dependence of farmers on market exchanges has also a qualitative side. Farmers regularly buy and sell commodities through arrangements which differ markedly from the text-book competitive market definition. For some inputs (straw, forage, calves, land, veterinary services, manual labor, and many household and consumer goods), it appears there exists a competitive market, as there are many buyers and sellers of these commodities. Farmers regularly work with the same people to obtain these goods and services, but, these enduring relationships are not interpreted as a source of un-freedom by farmers. The mere ability of farmers to easily change to a competitor is said to be a sufficient deterrent on overpricing to such suppliers. What we established from this observation is that while exchange is an act between two individuals, it appears to be influenced by the activities of other buyers and sellers in society, often unknown to these actors. For some inputs (pesticides, concentrates, seeds, planting material) there are but a few supplying companies. Many farmers say that this results into direct appropriation of economic value from them by these companies. Nonetheless, it appears that some farmers are not content to accept the terms of exchange, but are in a position to bargain individually by turning commercial partners against each other or collectively through group purchases. It was also said that these abilities are greatly diminished if farmers are in an immediate need for cash or indebted to their commercial partners. Going back to the concepts developed earlier, situated behavior reveals itself here as the varying ability and choice of farmers to challenge the rules constituting their position in relation to powerful suppliers.

Analysis of relations underlying the sale of agricultural products reveals an even richer picture, given the diversity and combinations of sale channels called upon among the interviewed farmers. Majority of farmers argue that for most agricultural products there is an oligopsony of food manufacturers and retailers, exerting undue influence on production conditions and terms of trade. In many of the cases studied, this belief has prompted farmers to partly organize processing and distribution activities themselves or find alternative partners. Yet, it may also translate into a shared sentiment among many whole selling farmers that they are playing a rigged game. Yet, the degree of this extraction of value is disputed: some farmers argue these companies have colluded against them to set prices and drive up their profits; others argue that downstream actors are also under the pressure of competition, which forces them to push down prices on farmers. This observation shows that actors are not determined to reach the same understanding of a similar situation. A few whole-selling farmers, not coincidentally larger farmers often with some personal experience in cattle trading, argue that there still is a free market. They say that current low prices are but temporary and due to overproduction, which will and should drive so-called inefficient farmers out of production. From, this vantage point, there is a form of fairness in market valuation: farmers are free to speculate, or move to on to produce different commodities, even though many conditions of production such as factor prices are to their frustration mostly beyond their control.

Leaving aside whether going market prices within whole selling chain are fair or not, farmers selling their products directly to the consumer appear to operate in a much more favorable price-environment. These farmers report that they are able to set the prices to their own production costs. An enviable position to most whole selling farmers, begging the question why the latter have not moved on to replicate it. Taking into account previous discussions, we would suggest that the different position is due to an altered relationship between the consumer and producer. Yet, this position is not arrived at easily, nor are the conditions present for each farmer. We've identified two main difficulties in setting up a viable direct selling system. The first is finding a way to organize processing the product without mainstream processing companies. This ability of farmers to process their product themselves depends on commodity-specific legal and technical, training and skills, labor and investment requirements to set up such a processing unit. For fresh vegetables in relatively small amounts, this is relatively easy; for meat however, this appears to be a high bar. Instead, many farmers resort to working with a local butcher to pack the meat, and sell the packages themselves. Looking back, we read that differences in social positions may influence farmers ability and willingness to establish particular personal relations with other actors. We notice, however, some antagonisms between such forms of cooperation, as some butchers see these direct selling farmers as direct competitors. Another option is setting up such processing units with other farmers to share investments and creating economies of scale, which appears at local level hard to set up, given the lack of trust among farmers; but if completed, worthwhile according to farmers engaged in such initiatives.

The second challenge for direct selling is to secure and expand a consumer base, which is willing to accept these presumably more fair trading conditions. On the one hand, this appears to be a question of investing time and resources in marketing activities (publicity, organizing festivities, social networking, personal contact with consumers), and on the other hand, of creating a distinct and desirable product. For farmers producing very large quantities, these are both rather daunting tasks. Instead of organizing distribution themselves, by-passing traders and the retail industry are also accomplished by selling to local butchers, supermarkets retailers, restaurants, or local food networks such as "Boeren en Buren" and "Voedselteams", which appear to offer terms of trade more fit to the specific situation of their enterprise. The commodities sold by direct-selling farmers, or farmers selling to alternative partners appear indeed to have a distinctive utility to their customers, meriting a higher price, which is clearly influenced by the farmer's specific production and marketing activities. This sets them apart from more generic commodities offered at mainstream outlets. Yet, one can question the extent to which these favorable price arrangements are isolated from the economic conditions faced by whole-sale and conventional farmers. Direct selling farmers admit they have to take into account the prices offered by local supermarkets and butcheries, as their customers do too. This shows that even relational exchanges are structured by impersonal relations. The same principle could also be applied to the restaurant owners, local food distributors, and butcheries farmers work with to circumvent the retail industry. Moreover, other farmers may jump into such niche markets as well, making appeals to the same customers, by undercutting prices and even overflowing the market, potentially leading to similar experiences as in the whole sale chain. Whereas buying appears to result in a different dynamic amongst farmers compared to selling, we do see this competitive logic replicated when farmers seek to secure a purchase of scarce resources such as land.

That farmers often act like competitors for resources and customers on the market, farmers say, strains the development of enduring personal relations and collaborations between farmers. This would constrain farmers to break the power of agro-food companies, and to take full advantage of the willingness of local consumers to pay more for agricultural products. Emery (2015) has argued that this lack of cooperation among farmers is a result of the individualist ideology among the farmer population, cultivated by agro-food companies. While some farmers indeed hint this could be a cultural phenomenon specific to the Flemish region, our framework implores us to take a step further to argue that there is an objective basis for such individualism. Given the particular nature of the social system farmers are inserted, they tend not only to believe they are competitors for resources and costumers, but they actually are. The existence of such impersonal relations between farmers across the board would explain the frailness of more relational arrangements. On one hand, such relations tend to hamper the constitution of stable solidarity networks favorable to agroecological production methods. On the other hand, the relative autonomy of farmers granted by this social system, also gives farmers the ability to get out of direct exploitative arrangements and to establish arrangements with other autonomously acting actors, which may be more lenient to their personal interests and perhaps to agroecology.

Perspectives

In this paper we outlined an analytical framework through which we sought to resolve some of the paradoxes surrounding market exchanges, that we came across during interviews with farmers. We touched upon several observations from our own field work that catalyzed these reflections, yet a full-fledged application of this framework on our data is still in the works. In future research, we will look how this framework allows to explain in causal terms paying equal attention to cultural rules, social relations and agency, why certain farmers take certain actions in line or against agroecological principles, and where it may fall short. In no way is the construction of an analytical framework specifically on market exchanges intended to trivialize the contribution of gendered, (domestic in particular) social relations and cultural rules to resolve our question. In fact, we believe that the layered approach proposed allows and encourages the flexible integration of critical perspectives on gender, class, ethnicity, animal subjectivity, into the analysis of alternative and not so alternative market-based food systems.

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THEME 5 – SMART TECHNOLOGIES IN FARMING AND FOOD SYSTEMS

Smart Farming indicates application of different forms of digitalisation in the agriculture sector, such as sensor driven agriculture (e.g. Precision Farming), the use of Big Data for analytical purposes to inform decision making, application of the Internet of Things (e.g. in quality control, producer-consumer relationships), and (autonomous) devices such as robots and drones. Digitalisation is not only a technological matter. It is also associated with new actors from outside agriculture (SMEs, upstream and downstream, service firms, etc.) and with new relations between actors. Whilst the potential benefits of these technologies are very easy to understand at a local scale, their potential impacts on farming systems have not been fully evaluated. Digitalisation is likely to affect and possibly disrupt the agricultural sector beyond the farm gate, influencing supply chain processes, logistics or consumer related information, knowledge and innovation systems, and can have pervasive social, economic, ecological and ethical consequences.

HOW DIGITALIZATION AFFECTS THE CAPACITY OF THE FARMING SECTOR TO ASSESS INNOVATION? THE CASE OF DIGITAL DECISION SUPPORT TOOLS FOR FERTILIZATION IN FRANCE.

Noémie Bechtet, Pierre Labarthe

INRAE France

Abstract: Promotors of precision farming claim these technologies can optimise agricultural production, value chains and food systems (Bellon Maurel and Huyghe 2017; Smith 2018). In the specific case of fertilization, digitalization relies on the use of digital decision support tools (DSTs) that aim at optimizing yield of the crop production and limiting fertilizer losses that can cause nitrogen contamination of groundwater. DSTs aim at helping farmers in overcoming economic and legal challenges.

Yet, several authors argue that there is a need for more evidence about the impacts of those tools on the sustainability of the farming sector (Balafoutis et al. 2017; Koutsos and Menexes 2017; Lioutas and Charatsari 2020). The question of the control of the recommendations given by these tools is particularly important. It is all the more relevant in a context where the privatisation and fragmentation of the supply of advice leads to new challenges about the control of the diffusion and evaluation of innovation (Knierim et al. 2017; Prager et al. 2016). Moreover, digitalization transforms internal logics of advisory suppliers, with for instance the emergence of new needs of capabilities for advisory suppliers (Fielke et al. 2020). In this paper, we aim at investigate the impacts of digitalization on the capacity of advisory suppliers of the farming sector to assess digital innovations that are subject to uncertainties and controversies.

To do so, we conducted in depth semi-structured interviews with designers and diffusers of DSTs in France. The aim was to identify the evaluation activities of the innovation made along this chain, with a specific focus on the role of advisory actors from the farming sector.

Preliminary results show that all actors realize intangible evaluation activities of the innovation. Private companies that design the innovation invest on data and analytics to build their expertise for such evaluation. Advisory suppliers from the farming sector (cooperatives, agricultural chambers and technical institute) support intangible but also tangible evaluation activities. Yet, they don't invest a lot of resources for evaluation activities.

Hence, this paper underlines the changing role of advisory suppliers: they use digital innovations to charge farmers for their expertise but their investments to assess the innovation is limited. Growing differentiation between their investments in front office activities and back office activities highlights the risk that advisory suppliers lose their capacity to assess the innovation. This leaves the space for agribusiness organizations that design digital innovations to set the rules for an evaluation based on the use of analytics and data.

EXPLORING THE ADOPTION OF INNOVATIVE SPRAYING EQUIPMENT

Alex Koutsouris[a], Vassiliki Kanaki[a], Emilio Gil[b], Paolo Balsari[c], Sebastien Codis[d], David Nuyttens[e], Spyros Fountas[a]

[a] University of Athens, Greece
[b] Universitat Politècnica de Catalunya, Spain
[c] Universita degli Studi di Torino, Italy
[d] Institut Francais de la Vigne et du Vin, France
[e] Instituut voor landbouw en visserijonderzoek, Belgium

Abstract

The purpose of this paper is to explore factors impeding the adoption of innovative spraying equipment as well as farmers' information and training needs (i.e. demands for/from extension/innovation support services). Data have been collected, in the framework of INNOSETA project, through a survey in 7 EU countries, based on a questionnaire addressing both adopters and non-adopters of innovative spraying equipment. A total of 348 questionnaires were collected and analysed using multivariate data analysis. Furthermore, 32 experts representing research/academia, the industry and extension/advisory organisations have been interviewed, based on an aide-memoire. The combination of the analyses of the two data sets produce interesting results concerning the support of the adoption of such technologies (including subsidizations, legislation, equipment characteristics, etc.) and the role of advisory/extension services.

Introduction[87]

Plant Protection Products (PPP) industry and research have been developing more sustainable, novel PPPs; at the same time, spraying technologies have experienced important improvements in terms of efficiency and safety, including in their development the latest advances in electronics, data management and safety aspects. But unfortunately, there is still an important gap between research developments and the actual use of the available equipment by farmers, especially the large number of small and medium producers with limited access to relevant information[88]. If this gap closes, then European agriculture could become more sustainable with minimum environmental, socioeconomic and human health impact. Therefore the need for agricultural stakeholders to gain knowledge of existing and future technological advancements in spraying technology as well as of adequate training in all of the European territory which will allow for the implementation of the EU legal framework and thus the production of food in a better and more sustainable way.

The H2020 project INNOSETA is organized to explore spraying application needs in the most commonly used crops (cereals, vegetables, orchards, vineyards and greenhouses) in seven European hubs (see below). The aim of INNOSETA is to set-up a Thematic Network on "Innovative Spraying Equipment, Training and Advising" designed for the effective exchange between researchers, industry, extension services and farming community. This network will link directly applicable research and commercial solutions and grassroots level needs and innovative ideas thus contributing to close the research and innovation divide in this area.

Among others, the INNOSETA project aims at assessing end-users' needs and interests and at identifying the factors that influence farmers' generation shift, adoption and diffusion of innovative spraying technologies. In this paper some of the results of the data analysis, collected through farmers' survey (see below) are presented.

[87] See INNOSETA project proposal.
[88] www.topps-life.org

Theoretical background

The literature review (Koutsouris and Kanaki, 2018) undertaken in order to provide an understanding of farmers' innovation-related behavior explored, on the one hand, main theories and models (e.g. Diffusion of Innovations – DOI (Rogers, 2003); Technology Appeptance Model – TAM (Venkatesh and Davis, 2000; Venkatesh and Bala, 2008); Agricultural (Knowledge and) Innovation Systems – A(K)IS (see Koutsouris, 2019); the Spiral of Innovations (Wielinga and Koutsouris, 2018),'Triggering Change' model (Sutherland et al., 2012), etc.) and, on the other hand, papers and reports related to spaying equipment and best practices adoption as well as elevant meta-analyses, focusing on the developed world.

With reference to the latter, for example, Thornton et al. (2017), in the first place, underline that the adoption of improved agricultural technologies and practices by farmers has often been less than expected despite demonstrated benefits. And quoting Orr (2012), they state that there are many contributing factors to that, including inherent limitations of supply-led approaches, limited attention to context-specificity and to farmers' priorities, and lack of appreciation of the socioeconomic, political and institutional contexts within which smallholder farmers operate.

Long et al. (2016) in their exploration of climate-smart agriculture (CSA) claim that its adoption in OECD countries is slow. Based on their literature review and a series of interviews in the Netherlands, France, Switzerland and Italy, they came to the conclusion that major impending factors are costs and other financial factors, overly complex language and 'jargon', and policy and regulatory issues (subsidies as well as lack of appreciation, in policy and research, of day-to-day farm realities) along with a lack of awareness of CSA and associated technological innovations.

Antolini et al. (2015) in their review of studies (largely concerning Brazil and the U.S.) on determinants of adoption of Precision Agriculture Technologies (PAT), show that the adoption drivers of major influence are related to: a) socio-economic factors (gender, age, education, family size, residence place, influence in decision making, experience in agriculture, experience with PAT, ability to obtain and process information, networking, membership in associations and cooperatives, financing and credit sources, risk aversion and organization level of producers in the region); b) agro-ecological (i.e. biophysical) factors (farm tenure, size, technologies and specialization, productivity, revenue, etc.); c) institutional factors which influence the behavioral change of the farmer (region and distance to input and output markets); d) information sources (access and perceived usefulness of consultants, extension services, technical companies, etc.); e) farmer's perception of the technological attributes such as relative advantage of certain technology, visibility of results, compatibility with existing technologies in the farm and the opportunity to experiment PAT; and f) technological factors, i.e. level of mechanization technology and adoption of technologies by the farmer.

Pignatti et al. (2015) based on a series of interviews with key-informants in Greece, Turkey and Italy, conclude that adoption of ICT and technological innovations in agriculture is strongly connected with a list of drivers including: a) farmers' socio-demographic characteristics: age, education, behavioural traits (entrepreneurial attitude, open-mindedness, attitude towards changes, propensity, fear and anxiety, etc.), knowledge and awareness; b) farms' structural features: land ownership, farm size, economic status, farm business and targeting markets, perspectives and planning, production type and farm's organization, location; c) innovations' features, such as: ease of use, usability, simplicity, compatibility with existing systems, flexibility, along with effectiveness, usefulness, observability of performance, reliability, degree of fitting, potential and perceived benefits, profitability, price/performance ratio and return on investments as well as provision of understandable feedbacks and ready-to-use information outputs; d) external environment: trusted and competent support system (re: farmers' awareness raising, decision process and evaluation); and, e) public funding, agricultural policies and market conditions.

De Baerdemaeker (2014) based on a number of examples of new technology adoption in the U.S. (tractors, milking robots, renewable energy technologies, rollover protective structures on tractors) note the difficulty of new technologies to replace existing technologies and highlight that the adoption of new technologies involves considerable change in farming practices. The author, in the same vein with Diekmann and Batte (2014), who explored the adoption of precision weed control technologies among U.S. farmers, states that the adoption of new technologies is affected by the perceptions of the potential users, learning requirements for their introduction, economics (costs both for the user and the supplier) and the financial or regulatory stimuli/incentives (including support in the form of demonstrations, extension services, etc.) from governments, nongovernment organizations, retailers, and/or consumers along with a systemic approach to integrated weed management (i.e. the building of robustness and redundancy into the system).

Pierpaolia et al. (2013), with reference to their literature review on Precision Agriculture (PA) technologies, claim that the most important aspects influencing the adoption of PA technologies are: farm size; costs reduction or higher revenues to acquire a positive benefit/cost ratio; total income; land tenure; farmers' education; familiarity with computers; access to information (via extension services, service provider, technology sellers); location. On the other hand, the intention to adopt depends on perceived 'usefulness' and 'ease of use' along with technology costs (a perception of both high monetary cost and cost related to the difficulty in the use of technology), the quality of soil and farm size and farmers' skills and relevant competences. They therefore suggest that on-farm demonstrations, free trial and support services (which promote the perception that new technologies are easy to use) along with the simplicity and compatibility of PA tools can enhance adoption.

Knierim et al. (2019) in their exploration of the adoption of smart-farming technologies (SFTs) in 7 European counties found out that farmers, although they have a positive view towards them, underline a broad range of barriers vis-à-vis their implementation. This, in turn, requires a better adjustment of technologies to farmers' needs and farm conditions as well as an improved enabling environment, in particular access to SFT related information, training and advisory services and to reliable digital infrastructure.

In their review Koutsouris and Kanaki (2018), along with Knierim et al. (2019), made clear that innovation adoption and diffusion is undoubtedly multifactorial with various factors, such as farmers' and farms' characteristics, biophysical, socio-cultural and institutional environment influencing the process of adoption, that is, if and how innovations are adopted; furthermore, the heterogeneity of both farms and farmers affects what is adopted, to what extent, and when. Moreover, the inconsistent evidence found in the literature review further points to the need for caution regarding, on the one hand, the use and measure of variables and, on the other hand, the different contexts (biophysical environment and cultural-historical patterns) within which research is conducted along with the characteristics of the technology under research. Reference has also to be made to the role of extension/advisory services and consultants which, in the framework of Agricultural Knowledge and Innovation Systems (AKIS), influence farmers' awareness, knowledge and skills. The literature review (theories and research results) provided the rational for the construction of both the questionnaire for the farmers' survey and the interview schedule for the experts' interviews carried out in the framework of the INNOSETA project.

Methodology

Our study covered 7 different European hubs: France, Greece, Italy, The Netherlands and Belgium, Poland, Spain, and Sweden. Five cropping systems were selected throughout all regions, i.e. arable crops, open field vegetables, orchards, greenhouses and vineyards (Table 1).

Table 1. Cropping systems per hub.

Spain	Orchards, Vineyards, Greenhouses
Italy	Orchards, Vineyards, Cereals
France	Orchards, Vineyards, Cereals

Greece	Orchards, Vineyards, Greenhouses
The Netherlands & Belgium	Cereals, Vegetables, Greenhouses
Sweden	Cereals, Vegetables, Orchards
Poland	Cereals, Vegetables, Orchards

Source: INNOSETA Grant Agreement

According to the project's Grant Agreement a) attention should be given to the fact that both adopters and non-adopters are included in the sample; b) the objective is to account and grasp the different needs and priorities of farmers in relation to their different socio-economic characteristics; and c) up to 50 interviews with farmers from the pre-classified groups should be conducted by the national partners, either personal or telephonic, using the specifically designed for this project questionnaire. Therefore, in the first place, it was decided to interview 50 farmers in each hub, comprising 25 adopters and 25 non-adopters per hub. Following, based on the contribution (%), in terms of utilized agricultural area (UAA), of each of the selected cropping systems per country a first estimation of the sample (no of farms/farmers per cropping system per country) was made. In order to grasp differences, we categorized the population (total number of farms/farmers) in each cropping system into size classes (ha.) following EUROSTAT 2013 data sets. Thus, based on the EUROSTAT 2013 data concerning the farm size classes for each of the cropping systems per country, a detailed sampling schedule (no of farms/farmers per size per cropping system per country) was put together. Finally, in order to have enough farms/farmers in the least represented cropping systems (ca 10 farms/farmers in each hub and around 30 farms/farmers in total with respect to each of greenhouses, open field vegetables and vineyards), with a view to data analysis, the sample was adjusted as shown in Table 2 (following again the farm size classes rationale in order to select farms/farmers).

Table 2. INNOSETA sampling (farmers' survey)

	Initial sampling	Adjusted sampling	Collected questionnaires
Cereals	200	144	142
Open field vegetables	18	34	29
Orchards	104	102	101
Greenhouses	10	32	32
Vineyards	24	40	44
TOTAL	356	352	348

The questionnaire comprised 102 closed, Likert-type and open questions divided in 8 sections: farm's characteristics; spraying equipment and machinery; innovative spraying equipment; adopters (or non-adopters) opinions on innovative spraying equipment; best management practices (PPP application); information seeking; farmer's innovativeness; and farmer's characteristics. Data were collected by partners, entered in appropriate EXCEL data basis (built by AUA) and analyzed with the use of SPSS for Windows (ver. 23.0).

Furthermore, a number of experts, i.e. those who are involved in agricultural technology development and innovation processes such as researchers/ academics, industry representatives, extensionists/advisors and/or farmers (representatives of cooperatives/ associations) were interviewed; the target was to interview 5 experts per hub. The interview guide comprised 18 open questions/topics addressing issues such as the current challenges and the role of innovative spraying equipment in overcoming them; the advantages and disadvantages of innovative spraying equipment for farmers; reasons for which farmers adopt (or do not adopt) innovative spraying equipment and the like. The expert interviews were conducted face-to-face, via telephone or Skype, recorded and transcribed to produce computer-generated documents and analysed per topic (exploratory analysis; Sarantakos, 2005). Overall 35 interviews were conducted. Emphasis was given to the expert groups *Research* (9), *Industry* (9) and *Advisors* (9) especially vis-à-vis the *Farmers*' group (3) as farmers were specifically targeted through the survey; 5 *Academics* were also inetrviewed.

Results

Farmers' survey

General characteristics

The vast majority of the interviewees own the spraying equipment they use (93%). In 20 out of the 348 cases they use a subcontractor (in 15 cases along with the use of their own equipment by themselves). The adopters of one of the innovative spraying equipment (selected by the project experts) are 204 (58.6% of the sample).

Farming is the primary occupation for 81.3% of all the interviewees. The majority of the interviewees operate their own family farm (83%); companies represent 16% and cooperative farms 1% of the sample.

The majority of the interviewees fall in the age category 40-59 years old (55%); farmers up to 40 years old account for 28% of the sample with farmers aged 60 years old and over being the 17% of the sample[89]. Up to 10 years of experience in farming have 24% of the interviewees with 29% having more than 30 years in farming. All other classes of experience (11-20 and 21-30) account, each, for 19-28% of the farmers[90].

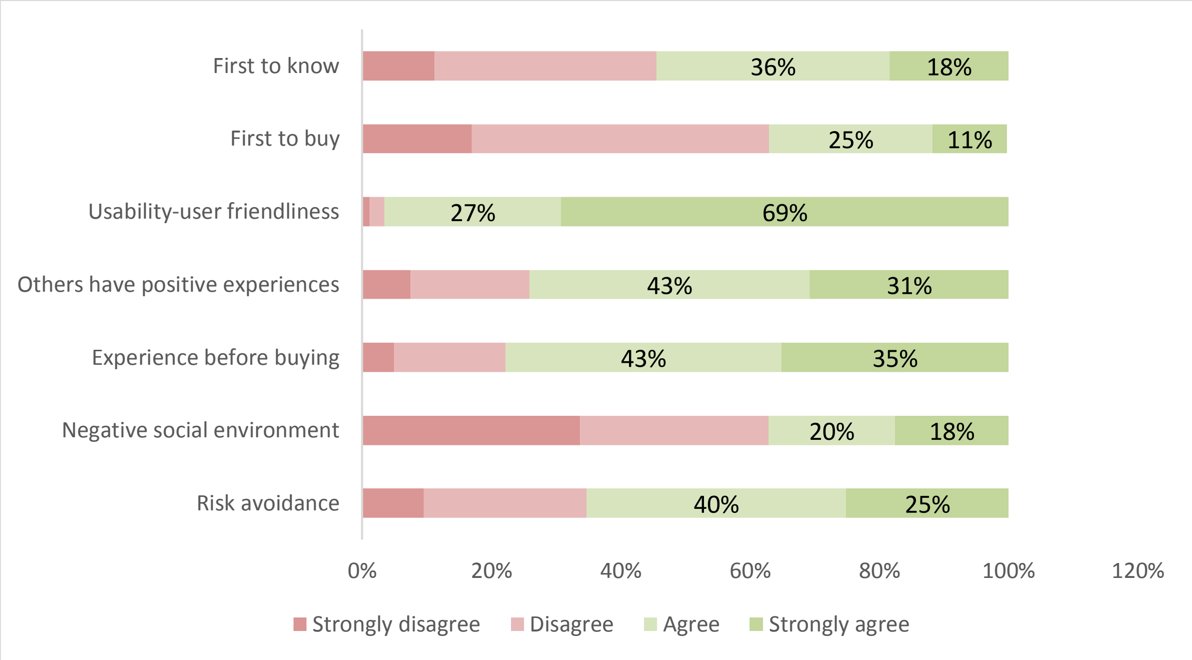
In general, the interviewees have good (secondary 26% and technical 42%) to higher educational level (university 22%)[91]. Furthermore, 93.6% hold the Training Certificate on PPP use according to the Directive 2009/128/EC while 61% have attended training courses in spraying machinery[92].

In general, adopters and non-adopters do not show any statistically significant difference in terms of age, gender, education and farm size (both owned and rented land) as well as years in farming and the existence of a successor - or not. Non-family farms (companies, cooperatives) are more likely to use innovative spraying equipment than family farms (P=0.001). Adopters and non-adopters do not differ in terms of holding a Training Certificate on PPP use but adopters are more likely to have attended a course on spraying machinery (P<0.10).

The interviewees claim that usability and user-friendliness are very important to them when they buy new things (97%) thus that they prefer to have some experience with something before they buy them (78%) and wait to buy new things, until they know that others have positive experiences with it (74%). Therefore, although they are the first to know about new machinery/technology in their social circles (54%) they are not the first to buy (63%). In general, they don't like taking risks (risk avoidance) with their farming business (65%). Finally, if interested, they would buy new equipment even if their (social) environment would be negative on it (63%).

[89] Farmers' age is differentiated per cropping systems with orchards and vineyards cultivators being younger.
[90] Farmers with orchards or vineyards are the least experienced in farming and with spraying applications (P<0.05).
[91] The majority of the farmers with greenhouses have primary and secondary education while the majority of the farmers with cereals and vegetables have technical education; more farmers (%) with orchards or vineyards have tertiary education as compared to the farmers with other cropping systems.
[92] Farmers with cereals or open filed vegetables are the ones who have been mostly trained on both PPP use and spraying machinery with farmers with greenhouses being the least trained in spraying machinery.

Figure 1: Farmer's innovativeness



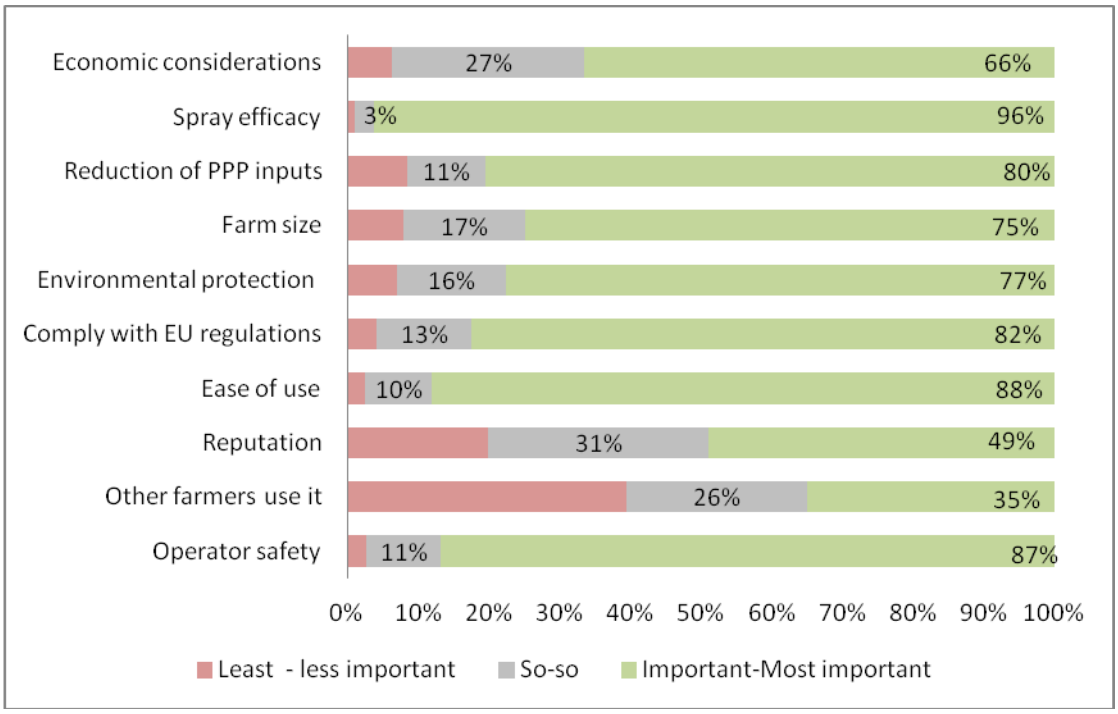
Adopters are more likely to be the first in their social circle of friends and relatives both to know about and buy new machinery/technology (P=0.000). On the other hand, non-adopters are more likely to wait to buy new things, until they know others have positive experiences with it (P<0.010) and prefer to have some experience with something before I buy it (P=0.001) as compared to adopters.

<u>Spraying equipment characteristics and adoption</u>

Concerning the criteria which affect interviewees' decisions on buying/choosing spraying equipment (Figure 2) 'spraying efficacy' (96%), 'ease of use' (88%) and 'operator safety' (87%) predominate followed by 'compliance with EU Regulations' (82%), 'reduction of PPP inputs' (80%), 'environmental protection' (77%) and 'farm size' (75%). 'Economic considerations' (66%) appear to be an important criterion (although less important than the aforementioned ones) with 'reputation (of the manufacturer)' (49%) and the fact that 'other farmers use it' (35%) being least important. Some farmers further added reliability (14 cases) and technical support/service (13 cases). Economic considerations are more important for non-adopters (P<0.05), while the reduction of PPP inputs and environmental protection are less important (P<0.05)[93].

[93] Economic consideration and farm size are less important for greenhouse growers; compliance with the EU rules is more important for farmers cultivating cereals and open field vegetables; and the fact that 'other farmers use it' is mostly important for growers with orchards/vineyards.

Figure 2: Criteria for buying spraying equipment



In general, adopters state that their innovative spraying equipment are easy to work with (96%), reliable (95%) and economically justified (90%); additionally, it is easy to get technical support for their equipment (87%) and they do not require a lot of maintenance (57%). Farmers also disagree with the statement that "sharing costs with other farmers has allowed you to use this spraying equipment" (83%).

Figure 3: Adopter's opinions on the innovative spraying equipment they have

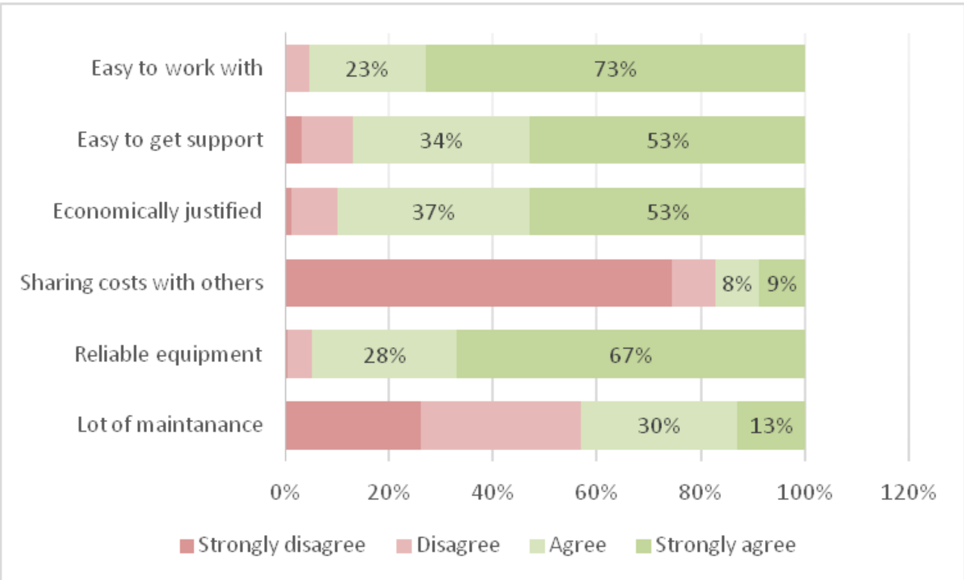
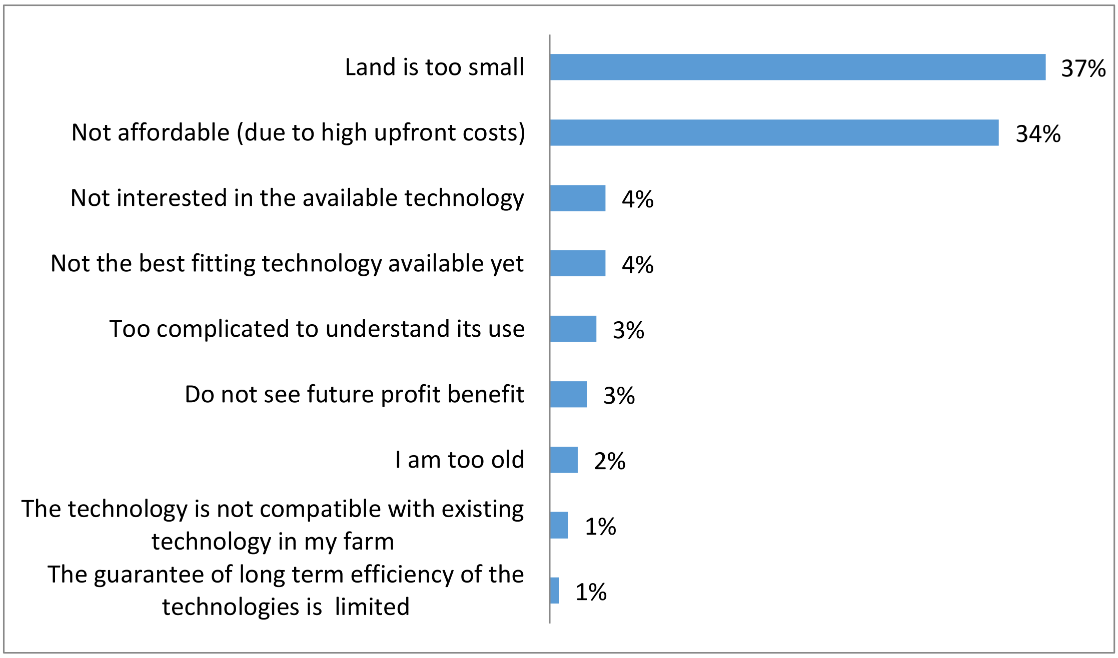


Figure 4: Most important reason for non-adopting innovatory spraying equipment



According to non-adopters the main reason for not having innovatory spraying equipment owes to their small sized farms (37%) and that they cannot afford it (34%). When five reasons pertaining non-adoption are aggregated, again the issues of affordability and small farms prevail (21% and 18% respectively)[94] with all other reasons ranging between 5% and 8%[95].

According to the interviewed farmers the most important spraying equipment characteristics that would make spraying equipment more relevant to farmers' needs (Figure 5) are long term reliability (95%), ease of use (94%) and operator safety (92%), followed by the availability of technical support (88%), compatibility with the existing machinery (86%), the reduction of environmental hazards (86%) and price (85%). Finally, easiness to install the equipment (79%) and economic benefits (68%) are important equipment characteristics for the majority. Adopters put more emphasis to the ease of use ($P<0.05$) and to the availability of technical support ($P<0.05$) than non-adopters[96].

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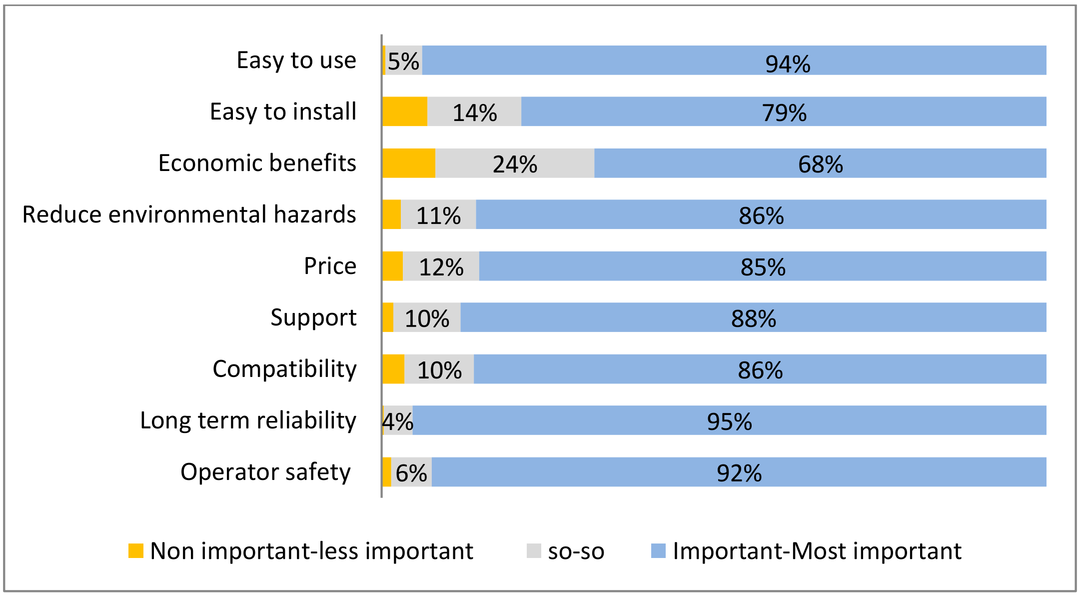
[94] The main reason per cropping system is as follows. For cereals and open field vegetables: not affordable (19%), small size (17%), do not see future profit/benefit (12%); for orchards and vineyards: not affordable (25%), small size (19%); for greenhouses: small size (24%), technical assistance not guaranteed (13%), not affordable (10%).

[95] Other refers to 30 answers among which the most important are: 'do not need it/my old machine works well' (11), 'not handy' (3) and 'not suitable for the morphology of the farm' (3).

[96] Economic benefits and compatibility with the existing machinery seem less important for cereal and open field vegetables cultivators while long term reliability seems to be more important for orchard/vineyards growers.

Figure 5: Characteristics that would make spraying equipment more relevant to farmers' needs



Interviewees were also asked about the incentives they would like to see in future policies to facilitate the acquisition of innovative spraying equipment. Two out of three asked for some kind of financial support, in principle the subsidization of the purchase of innovative spraying equipment. Other financial incentives, albeit with few supporters, include tax reductions (8), reduced equipment prices (18) and higher/fair prices for their produces (20); some also ask for non-repayable incentives (17) as well as long term mortgages or exemption from VAT. In parallel, some ask special treatment (increased support) for small-scale farms (10), support to certified and/or high precision equipment (3) as well as the reduction of bureaucracy (6).

Furthermore, one out of seven asked for training and technical support from independent (extension/advice) providers. Training is somewhat more frequently asked for as compared to technical support and information dissemination; the demand for demonstration, on top of the demand for technical support, is also interesting to notice (12 farmers).

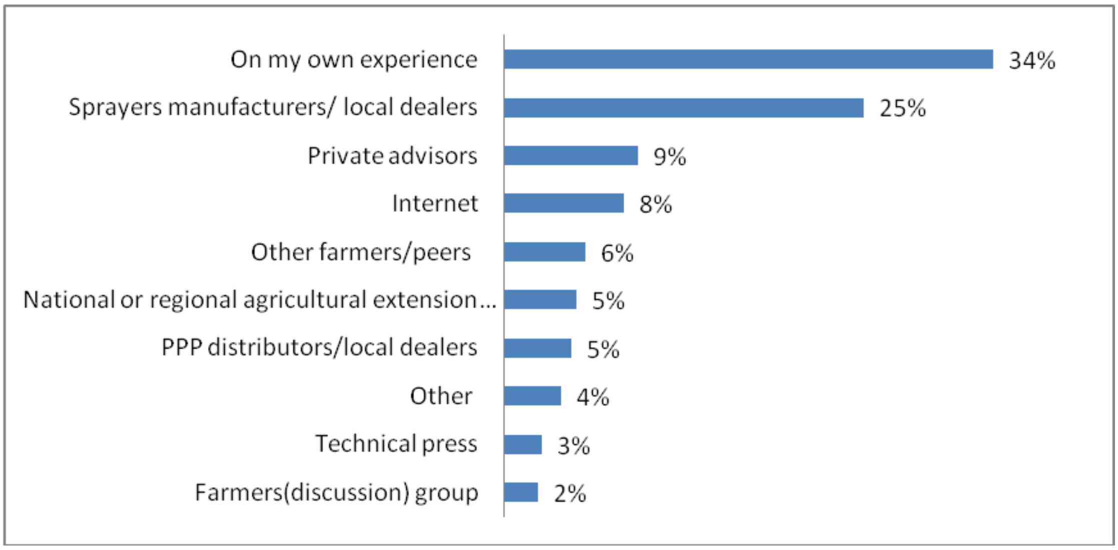
The change of regulations towards, for example, more strict inspections, compulsory use of Low Drift Nozzles and the like is supported by one out of ten. Another 10% maintain that the characteristics of the equipment (especially spraying efficiency followed by ease-of-use) could be a good incentive for adoption as well. However, around 5% of the farmers declare that they do not need/ wish to have any incentives

<u>Sources of information</u>

Regarding the most important source of knowledge/know-how on the use and operation of their spraying equipment is concerned (Figure 6) interviewees said that they rely on their own experience (34%) followed by information/advice from equipment manufacturers and dealers (25%) and advisors (private: 9% and public/cooperative: 5%)[97].

[97] The most important source of knowledge/know-how on the use and operation of their spraying equipment differs between farmers with different cropping systems. Farmers with cereals and open field vegetables mainly mention their own experience closely followed by the industry (sprayers' manufacturers, PPP distributors and their dealers); farmers with orchards/vineyards equally mention the industry and their own experience; and growers with greenhouses their own experience followed away by advisors (private or public).

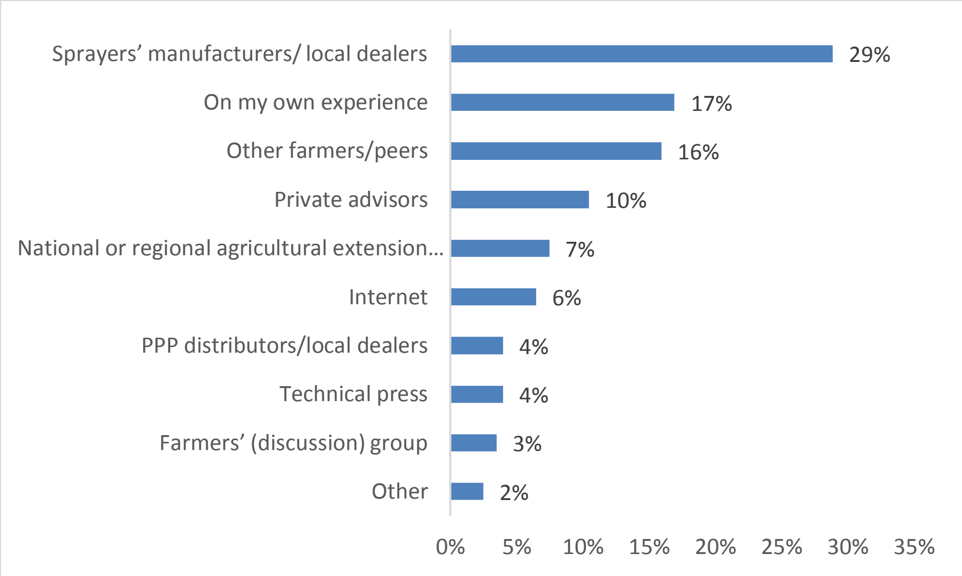
Figure 6: Most important source of knowledge/know-how on the use and operation of spraying equipment



Adopters and non-adopters seem to consider different sources of knowledge/know-how on the use and operation of their spraying equipment as being more important to them ($P<0.05$). Non-adopters rely much more on their own experience (as compared to adopters as well as to other sources of information) while adopters more on the industry (sprayers' and PPP manufacturers/dealers).

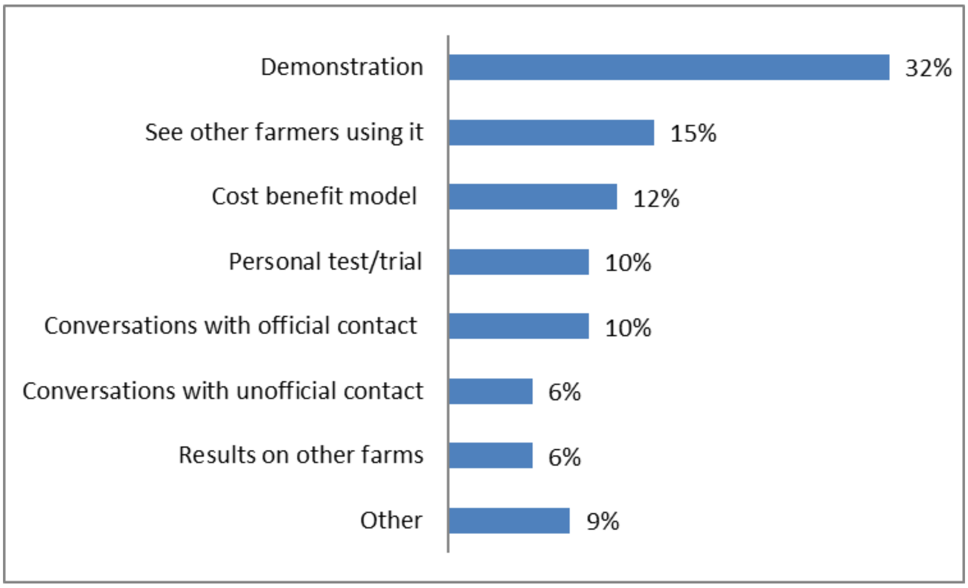
When the three most important sources of information are taken together again farmers' own experience (23% of all the answers to the questions) and equipment manufacturers and dealers (21%) predominate followed by advisors (private: 9% and public/cooperative: 5%), other farmers (9% other peers and 4% farmer groups) and the Internet (11%).

Figure 7: Adopters' most important information source on buying innovative spraying equipment



The most important adopters' source of information on buying innovative spraying equipment is sprayers' manufacturers/ dealers (29%) followed by farmers' own experience (17%), other farmers (16%) and private advisors (10%). All the other sources of information account for less than 10% each. When the three most inportant information sources are aggregated, sprayers' manufacturers/ local dealers (24%) along with other farmers/peers and their own experience (15% each) predominate. All the other sources of information account for less than 10% each. Additionally, the majority of the adopters did not test the equipment before buying it (70.6%)[98].

Figure 8: Information source non-adopters trust the most for buying innovative spraying equipment



Non-adopters said that the most important source/piece of information/test they would trust before deciding to purchase innovative spraying equipment are demonstrations (32%), other farmers using the equipment (15%), a cost-benefit model tailored to their farm (12%) as well as a personal trial or conversation with someone with advisory capacity (10%). 'Other' refers to 13 cases out of which 4 refer to extension/advisory service and another 4 to the Internet. When it comes to the three most important

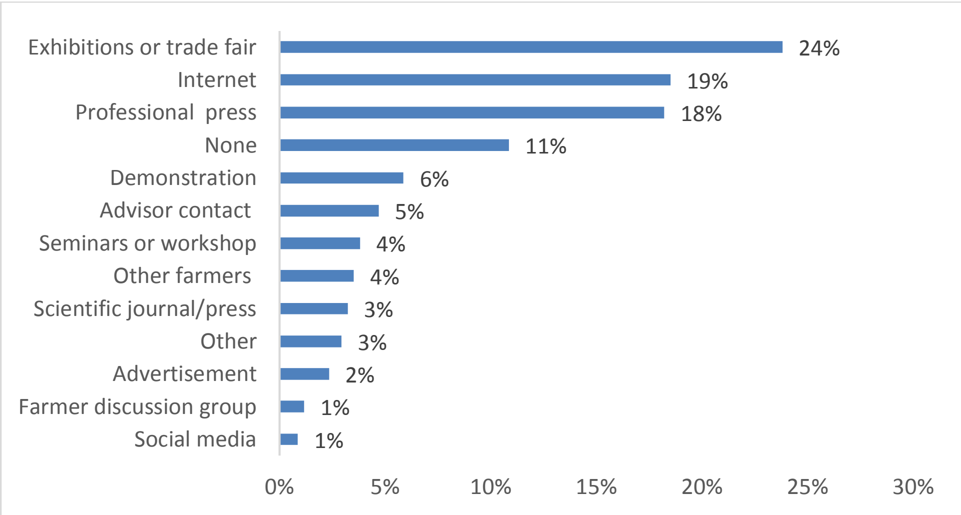
[98] This is mostly true for open field cultivations (around 27% of the farmers tested the machinery) while 50% of the farmers with greenhouses said they tested the equipment they were going to buy.

sources/pieces of information/tests demonstrations still lead (19%), followed by personal trials (15%) and other farmers using the equipment (13%). Conversations with someone with advisory capacity as well as results on other farms are equally important at 12% closely followed by a cost-benefit model tailored to their farms (11%) and conversations with peers and neighbors (9%).

Furthermore, non-adopters claim that they would buy innovative spraying equipment if they would get a subsidy (84%) as well as relevant training (68%) and to a much lesser degree if they could share initial (purchase) costs (28%).

The majority of the sample said that they visit agricultural fairs, field days/demonstrations, or exhibitions at least once a year (86%) – notably 51% more than once per year. Only 4% said that they have never visited such an event[99]. Adopters visit agricultural fairs, field days/demonstrations, or exhibitions more often than non-adopters (P<0.05).

Figure 9: Most recent source of information regarding innovative spraying equipment



Interviewees claim that the most recent source of information in which they sought out information in relation to innovative spraying equipment are exhibitions or trade fairs (24%), the Internet (19%) and professional press (18%), followed by demonstrations (6%), and advisors (5%). No relevant information during the year the interview was carried out (2018) was sought by 11% of the farmers. When the three most recent sources of information are aggregated exhibitions or trade fairs (23%), the Internet (16%) and professional press (14%) prevail, followed by demonstrations (9%), peers (8%), advisors (7%) and scientific journals/press (6%) .

Experts' interviews

In general, experts agree that, on the one hand, spraying equipment has to be further improved to face current challenges and, on the other hand, farmers must become not only aware of new technology but trained and supported on both new equipment and PPP. The industry representatives notice that technology becomes 'more expensive and more susceptible to failures' and this is an additional challenge for R&D while advisers underline the need to understand the complexity of on-farm (under real conditions) plant protection.

According to the experts, the main advantage of the adoption of innovative spraying equipment relates to spraying effectiveness and its environmental and economic (reduction of costs) benefits. Other positive aspects relate to operator health and safety as well as to compliance with legislation and work

[99] Farmers with different cropping systems manifest different behaviors. Three quarters of the farmers with green houses visit more than once a year; 90% of the farmers with cereals and open field vegetables visit at least once a year; 20% of the farmers with orchards or vineyards visit less than once a year or never.

comfort; professional pride and positive public image were also mentioned. These, in turn, are for the experts (although with differences in their ranking) the main incentives for farmers to adopt innovative spraying equipment, esp. when there are tangible results farmers can see ‘in their environment’.

On the other hand, experts unanimously pointed to the high initial (purchase) costs of such equipment as being their main disadvantage (for some, such costs are not justified), followed by (as aforementioned) the need for the continuous training of the farmers. Some also pointed to the fact that such equipment is complex and vulnerable - thus the need for quick access to technical support. It was also argued that farmers may feel insecure due to both the fact some technologies may have not been proven in practice (under real local conditions) and the continuous changes in technology and legislation. Farmers further underline the need to combine environmental protection with agronomic efficacy and farm/household economy along with relevant legislation.

According to the experts farm size (bigger farms), farmer’s age (younger farmers), education and ‘personality – mentality’ (technology enthusiasts, professional farmers, willing to experiment, open-minded) are most likely to be the factors that characterize the adopters of innovative equipment and practices. Production intensification, membership in farmers’ groups or companies (vs. family farms) and public image were also mentioned, esp. by industry represenatives, as affecting adoption. According to extensionists the forefront factor pertaining adoption is farmers‘ environmental consciousness. Farmers additionally point to social pressure and legilation.

With regard to the main constraints vis-à-vis the adoption of innovative spraying equipment and practices experts point, besides affordability, to farmers’ technophobia. The latter relates to the lack of training, farmers‘ low educational level, unawareness about new technology, along with occasionally contradicting messages from the industry, confusion about legislation and equipment vulnerability. Advisors and researchers further point to unsuitable farms’ conditions and the pressure of farmers‘ immediate social environment while farmers also mention the fast developments in technology (including the expectation for better and cheaper equipment).

Given their preceding views, all experts state that the affordability of the innovative spraying equipment and the visibility/demonstrability of their benefits are key in supporting their wide adoption/use; the industry believes that profitability is a preceding factor. Other characteristics of the technologies, such as ease of use (user-friendliness) and maintenance, flexibility/adaptability, and reliability in time, are equally important. Farmers once more point to the need for technology to focus both on environmental protection and farmers‘ interests.

Experts thus support the subsidization of the purchase of innovative spraying equipment (especially for small farms). Scientists do so mainly due to the need to “renovate the sprayer fleet” – although there are also reservations as to the effectiveness of subsidies and the burden of the accompanying them bureaucratic procedures. On their part, industry representatives underline that subsidies should be targeted to equipment which meet certain requirements (for example, certified as environmentally friendly; precision spraying). Moreover, experts maintain that subsidies should not be the sole measure taken; stricter legislation (for example, ban the marketing of the least efficient sprayers or reward implementation of best practices) – given that such legislation will be coherent, clear and enforced (i.e. control mechanisms are put in place) along with information campaigns concerning the benefits of innovations, are deemed equally important. Farmers once more point to the the need to bring agricultural and environmental components together.

Furthermore, experts agree that the main R&D target groups are the most dynamic businesses, including big entrepreneurial family farms and companies (professionals/entrepreneurs and/or early adopters comprising potential clients) along with younger farmers and the most profitable crops. Therefore, according to some scientists (academics and researchers), despite the need for R&D to take into account farmers’ needs farmers are actually placed at the end of the innovation pipeline and do not have any chance to influence what happens at the other end; additionally, the low level of farmers’ education negatively affects the expression of precise and realistic demands to the industry. On the other hand, it is maintained that small-scale, local/regional companies take a closer look to their clients' needs as compared to larger national and/or international companies. Scientists said that innovation development is a process with its own dynamics and, although in spraying most developments are marginal/ incremental rather than radical ones, it is not possible to take into account all kinds of demands or to produce technology which will be suitable for everyone. Industry's and research programmes' policies affect the uptake of innovative ideas (including farmers' ideas). Advisors and farmers largely agree with scientists; for advisors the industry is more subject to pressures from legislation rather than to demands from farmers while farmers argued that the technology is mainly supply-driven than demand-driven resulting in a 'mismatch'. Contrary to such arguments the industry representatives maintain that there is two-way communication between farmers and the industry as well as that both actors are very important in technology development and thus their relationships must be improved.

Scientists underline the importance of extension/advisory services whose role is, on the one hand, to contribute to the wide diffusion of innovations (equipment, practices, PPP) through the provision of independent (neutral; objective), evidence-based information and practices (including training) to farmers and, on the other hand, to identify farmers' needs and inform industry. Among others, advisory services can assist farmers through independent tests and demonstrations as well as through the examination of the suitability of recommended best practices on their fields. Furthermore, extensionists claim that the establishment of communication links between the main stakeholders is imperative.

The experts note that despite the need for all the actors (possibly) comprising AKIS (re: the branch of innovative spraying technologies) to cooperate there is a profound lack of a comprehensive discussion/innovation platform on spraying equipment and difficulty to bring stakeholders together (especially on the horizontal level, i.e. competing manufacturers). They argue that extension/advisory services (should) intermediate between stakeholders, especially between farmers and researchers (farmers <-> extension <-> research) since they have good relationships with both of them. According to the scientists, the weakest link is policy, owing to its excessive slowness in decision-making and bureaucratic inefficiency along with the fact that decision-makers usually consult stakeholders other than farmers when they take measures about farming. The second most serious gap, according to scientists, is that between farmers and the industry; even if manufacturers interact with farmers they usually interact with a very small group which is not representative of the heterogeneity in farming. Such weak links between the interested parties result in gaps; the most characteristic one is the gap between theoretical/experimental developments and their applications in practice.

Conclusions

Innovation adoption and diffusion is undoubtedly multifactorial (Rogers, 2003); as aforementioned the heterogeneity of both farms and farmers affects what is adopted, to what extent, and when. In this piece of work, an attempt to identify factors impeding the wide adoption of innovatory spraying equipment was undertaken along with an exploration of the role of extension/advisory services in this regard.

In the first place, it is intresting to note that (most of) the interviewees/ farmers and (most of) the experts converge in their opinions concerning the measures to be taken to enhance the uptake of innovative spraying equipment. Experts agree with farmers for the need of targeted subsidization (certified machinery, best management practices, possibly more favorable for smaller farms). However, subsidies should not be the sole measure taken; stricter legislation and its enforcement, information campaigns, farmers' training and technical support by independent extension/advisory services are equally important.

Furthermore, equipment have to be improved in terms of the safety and comfort of the operator and ease-of-use, besides spraying efficacy and environmental and economic performance. The suitability of equipment for small farms as well as for difficult topographies has also to be underlined. Attention should be also given to farmers' demand for the better balance between environmental and agronomic performance of new technologies (spraying machinery and PPP).

As abovementioned, interviewees/ farmers asked for training and technical support from independent (extension/advice) providers while the interviewed experts, with reference to the low uptake and the complexity of new equipment, also stress the need to provide farmers with continuous training and technical support. On the other hand, it is important to notice the weak position of extension/advisory services among farmers' information sources on spraying equipment as well as the considerable percentage of farmers (esp. non-adopters) who are based on their experience. The need for extension/advisory services to engage with 'practice' activities like demonstrations[100] and participation in exhibitions or trade fairs as well as to assist farmers with their own trials and evaluations has been clearly shown, besides of course the intensification of other dissemination activities and the establishment of contacts with the 'hard to reach farmers' (including the internet and social media).

Finally, the lack of functional AKIS/ innovation platform in the branch of spraying technologies has to be underlined since it results in gaps which, although rather known to the actors concerned, are not bridged (with farmers in the weakest position, or isolation). In this respect, extension/advisory services seem to be in the best position (as compared to the other actors) to play an intermediation role (see Koutsouris, 2018), i.e. to negotiate with other actors the creation of the relevant AKIS network.

Despite the particular scope and sampling methodology followed in the INNOSETA project, these results may be of wider interest. The importance of exploring the topic of the adoption of innovative spraying equipment and the (potential) role of extension/advisory services is shown; further exploration is needed and is thus very welcome.

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FORESIGHTING THE FUTURE OF DIGITAL AGRICULTURE: FOUR PLAUSIBLE

Aysha Fleming[a], Andrew Terhorst[b], Bruce Taylor[a], Emma Jakku[a], Simon Fielke[a], Cara Stitzlein[b]

[a] CSIRO, Land and Water, Australia
[b]CSIRO, Data61, Australia

Abstract: Digital technologies offer agricultural systems around the world a myriad of potential opportunities. For some, the future has never looked brighter, for others it is more uncertain. To prepare for change and to understand the potential opportunities and consequences of smart farming technologies, fore-sighting is a recognized methodology to anticipate, learn and design strategies for change. Scenarios produced through fore-sighting are not guarantees of the future but ways to spark thinking and prepare for the unknown. This paper presents the results of a foresighting workshop that examined future smart farming scenarios in Australia. The workshop was conducted in Brisbane, Australia, in 2018 with leaders of CSIRO's 'Digiscape' future science platform - an initiative to build common big data infrastructure to transform decision-making and environmental action in Australian agriculture. The fore-sighting workshop posed the question: what does the future of Australian agriculture look like and what are the implications? Key social, economic, environmental, and technological trends that might impact agricultural knowledge and advice networks and supply chains, both in Australia and more globally, were presented and refined at the workshop. From this four plausible future scenarios emerged. Eight trends were identified: Accessibility and Connectivity; Proliferation and Integration; Consumer Demand and Traceability; Human and Social Capital; Globalisation; Farm Business Model Change; Environmental Stewardship and Services; and Resource and Environmental Uncertainty. From these eight trends, two axes were chosen to capture the most important drivers of change. The axes were: Resource and Environmental Uncertainty (vertical axis) and Farm Business Model Change (horizontal axis). The two axes created four quadrants which were each worked through by a different group at the workshop to produce four scenarios describing Australian agriculture in 2030. They were named: "Struggling", "Innovating", "Surviving" and "Thriving".

The scenarios serve as simple outlines of complex realities from which short to medium term inferences relating to digital agriculture can be explored and understood. They are not mutually exclusive or guaranteed, but they offer insights into potential issues and opportunities for digital agriculture development in Australia and more broadly. The implications identified from the scenarios, with lessons and potential applications for Digiscape and other digital agriculture projects relate to potential changes in farm business models, potential opportunities for new and improved decision making, both by landholder and others, potential beneficiaries and inequities of new technologies and interactions with digital technology and other components of food supply chains. The paper describes the scenarios and their implications in specific terms (changes that have been made to the strategic orientation of Digiscape) and more generally (lessons for other initaitives around the world).

POTENTIAL OF USING ICT TOOLS FOR CROP DISEASES MANAGEMENT AMONG HETEROGENEOUS FARMERS IN RWANDA

Michel Kabirigi[ab], Frans Hermans[b], Zhanli Sun[b]

[a]Rwanda Agriculture Board (RAB), Research department, Rwanda.
[b]Leibniz Institute of Agricultural Development in Transition Economies (IAMO), Germany.

ABSTRACT

Social interactions among farmers, extension agents, and government officials play a critical role in knowledge development and exchange, uptake of new practices, collective decision-making in agricultural practices. This is especially evident in developing countries where small-holder farming systems and subsistence agriculture prevail. Smartphones and new communication tools are likely to transform the way information exchange and social interactions take place. However, how these ICT developments will influence the communication and social interactions among farmers, and decision-making of farmers are intriguing questions, yet to be studied. Thus the aim of this study is to evaluate the use and experience of ICT of banana growers in Rwanda within the context of establishing an effective method for prevention and control of Banana Xanthomas Wilt (BXW), an infectious plant disease. Specifically, we want to assess whether farm clusters associate with the different behaviors and perceptions of the use of ICT. A structured questionnaire was used to collect household information from banana growers (n=690) in 8 representative districts across eight (out of ten) major agro-ecological zones within Rwanda. A combination of principal component analysis and cluster analysis was used to develop a farmer typology of banana growers. Three types of banana growers were identified, namely, i) Beer banana farmers characterized mainly by proportion of land allocated to beer banana and proportion of beer banana sold, ii) Livestock based farmers characterized mainly by high tropical livestock unit and higher education years of household head, and iii) Cooking banana farmers characterized mainly by proportion of land allocated to cooking banana and proportion of cooking banana sold. We then conducted a statistical analysis to regress the use of ICT on the farmer typology and other socioeconomic control variables. Results showed that cooking banana based farmers are more likely to own a smart phone and perceive ICT as very useful in effective control of BXW whereas beer banana farmers are less likely to own a smart phone; and they tend to perceive ICT as irrelevant in controlling BXW. Beer banana farmers are mainly limited by not knowing how to use these services which is associated with their low level of literacy while Livestock farmers prefer to get information from other sources. The studied farmers provide potential for using ICT (Mobile based) extension services however beer banana farmers, less likely to own smart phones, are limited to few options.

INTRODUCTION

Agricultural development is both crucial and global issue with increasing demand for the world to feed its population. The fact that the increase in yield does not grow in pace with the increase in food demand the food gap is expanded day by day signposting the potential of food shortage in the future (Long et al., 2015). Plant disease is one of major threats seriously compromising food production thus negatively affecting food security (Strange and Scott, 2005). For example the Banana Xanthomonas Wilt (BXW), caused by *Xanthomonas campestris* currently known as *Xanthomonas vasicola pv. Musacearum* (Biruma et al., 2007), has become the number one threat to banana intensification programs aiming at availing food for the increasing population in East and Central Africa (Nakato et al., 2014). Banana is a key crop, especially in eastern and central part of Africa, in the livelihoods of smallholder farmers occupying almost a quarter of arable land, contributing more than 50% to the diets (Gaidashova, 2006; Nkuba et al., 2015) and grown by 90% of households (Nsabimana et al., 2008). The crop is grown for 3 main purposes namely for cooking (41% of total banana cultivated area), for dessert (14% of total banana cultivated area) and for beer (45% of total banana cultivated area) in Rwanda (Bagamba et al., 1998; Nsabimana et al., 2008).

ICT tools and especially mobile phone-based ICT technologies have recently come up as a potential way of reorganizing extension system (Schut et al., 2016). The idea is that mobile phone-based ICT technologies, including smartphones and new communication tools, offers an opportunity to innovatively improve disease control efforts through timely surveillance of incidence. ICT technologies can improve communication among farmers themselves in the context of informal knowledge sharing networks which are developed because of limited operation in space of extension agents farmers create the (Vouters, 2017). A review by McCampbell et al. (2018) distinguished four intervention pathways for the application of citizen science and ICT within the context of effective control of this banana diseases in Central and East Africa. These four pathways are 1) providing data for prevention, 2) providing technical information for control, 3) providing knowledge to influence decision making, and 4) improving collective action. From this perspective, it is argued that the use of mobile based communication platform will enhance self-organized networks to timely diagnose BXW emerging outbreaks and to exchange knowledge which will lead to timely actions for prevention rather than control (McCampbell et al., 2018).

Although phone based ICT tools thus potentially offer many benefits the question of how these ICT developments will influence the communication and social interactions among farmers, and their subsequent decision-making are yet to be studied. As a first step towards answering this question, we aim to assess the different attitudes related to the use and perceptions of ICT related agricultural services (especially mobile phones) by different types of farmers. This is necessary because farms are diverse and heterogeneous in terms of socio-economic conditions which affect their behaviors on resource use and priorities hence the better understanding of this might explains differences in behaviors regarding production and consumption in agricultural production system (Tittonell et al., 2005; Barnes et al., 2011). Most of projects in agriculture are designed assuming that farmers are homogeneous hence interventions are similar to all. To some extent the low uptake of agricultural innovations has been associated with the failure of proper consideration of smallholder farm diversity (Coe et al., 2016; Hammond et al., 2017). A similar problem can be found with regard to the potential use of ICT. Although there have been studies to understand factors affecting farmers in adopting phone based services in agriculture (Islam and Grönlund, 2011; Adegbidi et al., 2012; Tadesse and Bahiigwa, 2015) these studies have also assumed that farmers are homogenous.

In this paper we use farm clustering to classify farm households based on socio-economic characteristics to understand how they would react differently to the adoption of new technologies based on their diverging priorities (Hammond et al., 2017). In this study we thus take farm diversity into consideration by discussing the use and perception of mobile based information delivery against banana farm clusters. Findings of this study will provide significant background information to projects targeting the use ICT based intervention for improved agricultural management.

METHODOLOGY

Study area

This study was performed in Rwanda, the country located in East Central Africa between latitudes 1°04’ and 2°51’ South and longitudes 28°45’ and 31°15’ East. In terms of area covered by banana in Districts, Muhanga, Gatsibo, Karongi and Rulindo have higher land allocated to banana production, equivalent to 22.5%, 11.1%, 10.1% and 7.1% respectively of the total agricultural area.

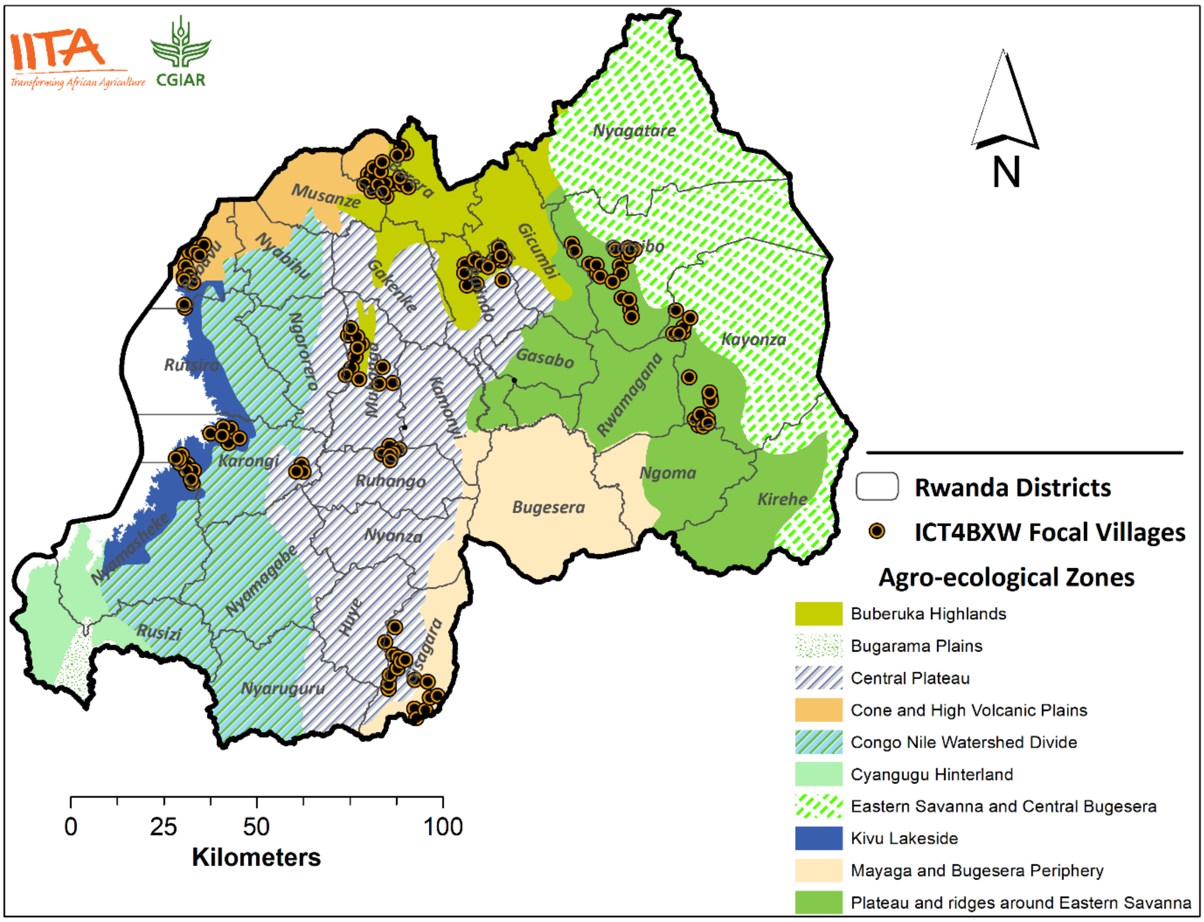


Figure 35: Study area

Sampling and data collection

The household survey was conducted in the period of July - August 2018 by trained RAB technicians from Banana program to establish the baseline of "Citizen Science and ICT for advancing the prevention and control of Banana Xanthomonas Wilt (BXW) in East and Central Africa" project. Within 8 selected districts Sectors and Cells were selected based on expert input from the district and sector agronomists. Stratified sampling was used to select villages, strata being the distance from District extension office and the incidence of BXW. Two criteria were considered when selecting villages: (1) distance between the village and the district headquarters whereby three-point scale was used (close, medium, and far) and (2) Level of BXW incidence whereby three-point scale was used (low, medium, high). Incidence levels were determined based on reports from sector and cell agronomists and field observations from RAB banana experts and technicians when passing through the village. The sampling team aimed for selection of villages with a minimum distance of 5km or a non-intervention and non-control village in between two selected villages. The selection of farmers considered gender of household head where amongst 5 farmers selected in each village 2 were female headed household and female enumerators were assigned to interview this category of farmers. The total expected number of farmers interviewed was 720 however only 690 farmers were interviewed reason being the lack of villages that falls within the 'long distance to the district headquarters' category in Rubavu District thus reducing the number of village from 144 to 138. The questionnaire used open, half open and closed questions, retrieving information at household level to establish baseline information for the "Citizen Science and ICT for advancing the prevention and control of Banana Xanthomonas Wilt (BXW) in East and Central Africa" project shortened as ICT4BXW. For this study we only analyze those questions of the survey that included ownership and use of mobile phones as ICT tool, relevance of ICT in BXW management and challenges farmers are facing in relation to the use of ICT in agriculture. General questions such as gender, age, education level characterizing respondents were included for analysis.

Data analysis

Principal component analysis (PCA), a data reduction method unmasking, through orthogonal transformation, hidden structures in a dataset was used to identify variables more explaining farm differences and identify components to be used in grouping farmers into clusters (Kourti, 2009; Barnes et al., 2011). Clustering was performed using hierarchical method where hierarchy bring close a tree like structure called dendogram and clusters are formed by connecting k+1 cluster solution into two clusters using group resemblances. Both descriptive and inferential statistics were performed. Column means was run to identify significant differences between farm clusters at 95% probability level. Dichotomous outcome variables of interest were subjected to a binary logistic regression analysis with independent explanatory dichotomous, categorical and continuous variables. We used FactoMineR an R package dedicated to multivariate data analysis (Lê et al., 2008) for principle component analysis and gplots R package to calculate and plot means (Bonebakker et al., 2012) in version 1.1.456 – © 2009-2018 RStudio.

RESULTS

PCA and clustering results

The figure 2 shows the scree plot highlighting 10 components, from a total of 12 variables which were included in PCA, whereby five components with eigenvalues greater than 1 retained for cluster analysis explain 63.3% of the total variation. The figure also presents variables contribution to the construction of two main components (explaining 32.5% of the variation) where the land allocated to beer banana or cooking banana are the main variables contributing whereas extension number received contribution is not so significant.

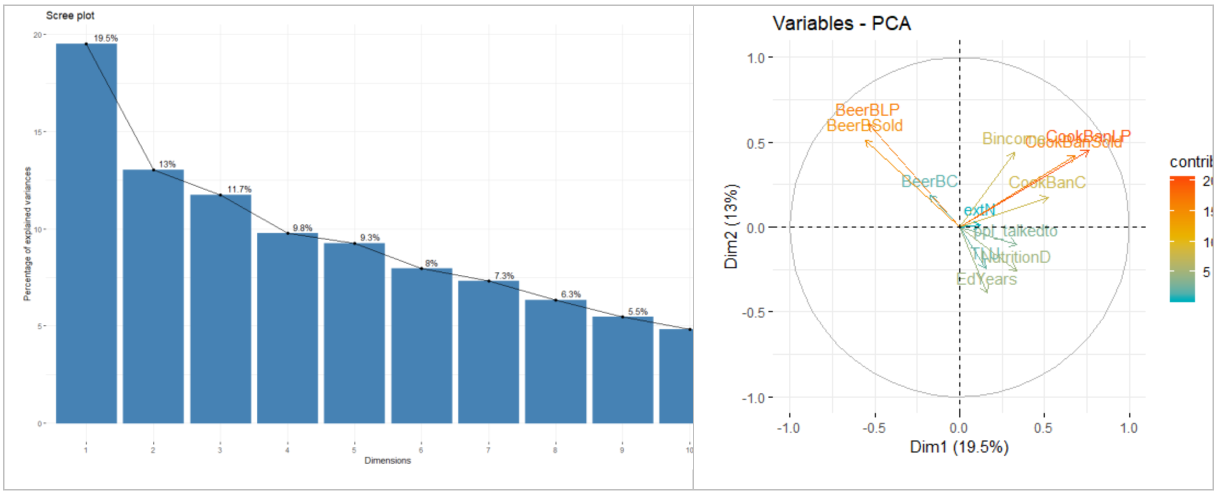


Figure 36: Principal component analysis Scree plot and contribution of variables to components

The table 1 presents identified variables responsible for farm heterogeneities which can be summarized in 3 groups namely farm/respondent characteristics (Nutrition Diversity and Education Years), type of banana grown, distribution in the field and use (Cooking or beer banana with their respective proportion of land allocated to them, banana income and promotion sold and consumed) and access to extension services (Extension number and People talked to). By observing the v.test values, which indicate if the mean of the cluster is lower or greater than the overall mean, we could name clusters considering that higher values of v.test show variables that are more associated with the cluster. The cluster one is more associated with proportion of beer banana sold, proportion of land allocated to beer banana and proportion of beer banana consumed as highlighted in the table thus they are named Beer Banana

Farmers (BBF). The second cluster which is more associated with tropical livestock unit (Livestock numbers converted to a common unit), education years and nutrition diversity is named Livestock Based Farmers (LBF) whereas the third cluster named Cooking Banana Farmers (CBF) is more associated with proportion of land allocated to cooking banana and proportion of cooking banana sold and consumed.

Table 19: Variables responsible for farm heterogeneity and resulting clusters

Variable	V.test Mean C1	V.test Mean C2	V.test Mean C3
Nutrition Diversity	-5.12	**2.55**	2.89
Extension number	-2.02	**-**	-
Education Years	-3.10	**2.91**	-
Tropical Livestock Unit	-2.56	**3.38**	-
Cooking Banana Land P.	-11.20	-8.38	**20.62**
Cooking Banana P. Consumed	-9.13	-7.81	**17.81**
Cooking Banana P. Sold	-9.60	-8.26	**18.78**
Beer Banana Land P.	**16.77**	-12.41	-5.30
Beer Banana P. Consumed	**6.39**	-5.60	-
Beer Banana P. Sold	**19.45**	-14.27	-6.27
Banana income	-	-4.94	5.77
People talked to	-4.15	-	3.95
Named according to V.test	***Beer Banana farmers(BB)***	***Livestock based farmers(LB)***	***Cooking Banana farmers(CB)***

Characteristics of respondents by clusters

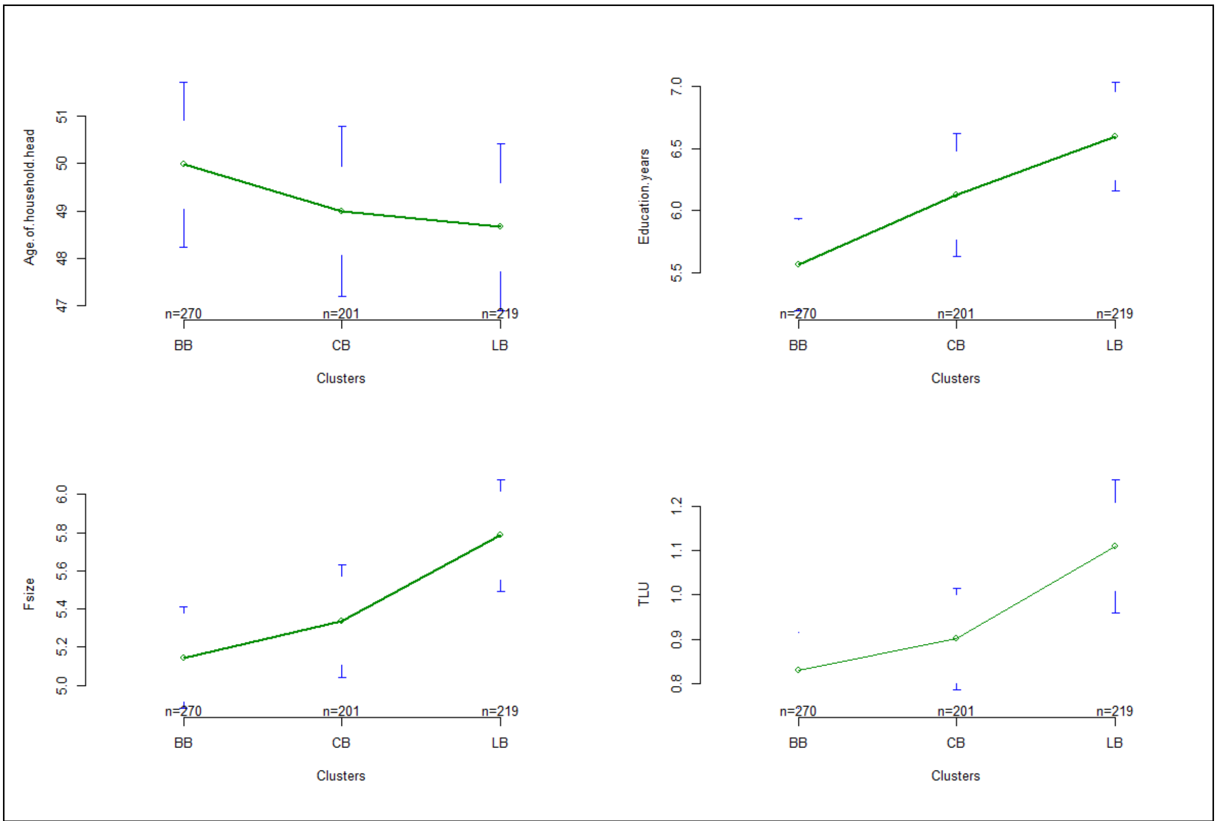
Table 2 presents characteristics of household and respondent by banana farm clusters in terms of gender and farm experience in BXW infection. Majority of respondents (57.8%-64.4%) were males but the difference was very high in livestock based farmers. There was no significant difference between typologies in terms of having experienced or experiencing BXW (Table 5) suggesting that they are all equally vulnerable.

Table 20: Descriptive statistics characterizing household and respondent by banana farm clusters

Variable	Category	Beer BF(270)	Livestock BF(219)	Cooking BF(201)	χ2tests of independence
Gender of respondents	Female(276)	(114)42.2%	(78)35.6%	(84)41.8%	$\chi2(2)$= 2.58 NS
	Male(414)	(156)57.8%	(141)64.4%	(117)58.2%	

Experienced BXW	No(225)	(98)36.3 %	(64)29.2%	(63)31.3%	χ2(2)= 2.96 NS
	Yes(465)	(172)63. 7%	(155)70.8%	(138)68.7%	

The figure 3 summarizes means of quantitative variables characterizing respondents by clusters. The average age of beer banana farmers (49.9±14.8 years) was slightly higher than the rest of banana farmers. The livestock based farmers were significantly highly educated (6.6±3.3 years of education) than other groups. The average family size and tropical livestock unit was higher for livestock based farmers while cooking banana farmers had higher banana income (15.4±41.0*10000 Rwandan Francs) and proportion of cooking banana sold. Concerning the average number of people talked to, an indication of information exchange regarding BXW management, cooking banana farmers had high average number (18±46 people).



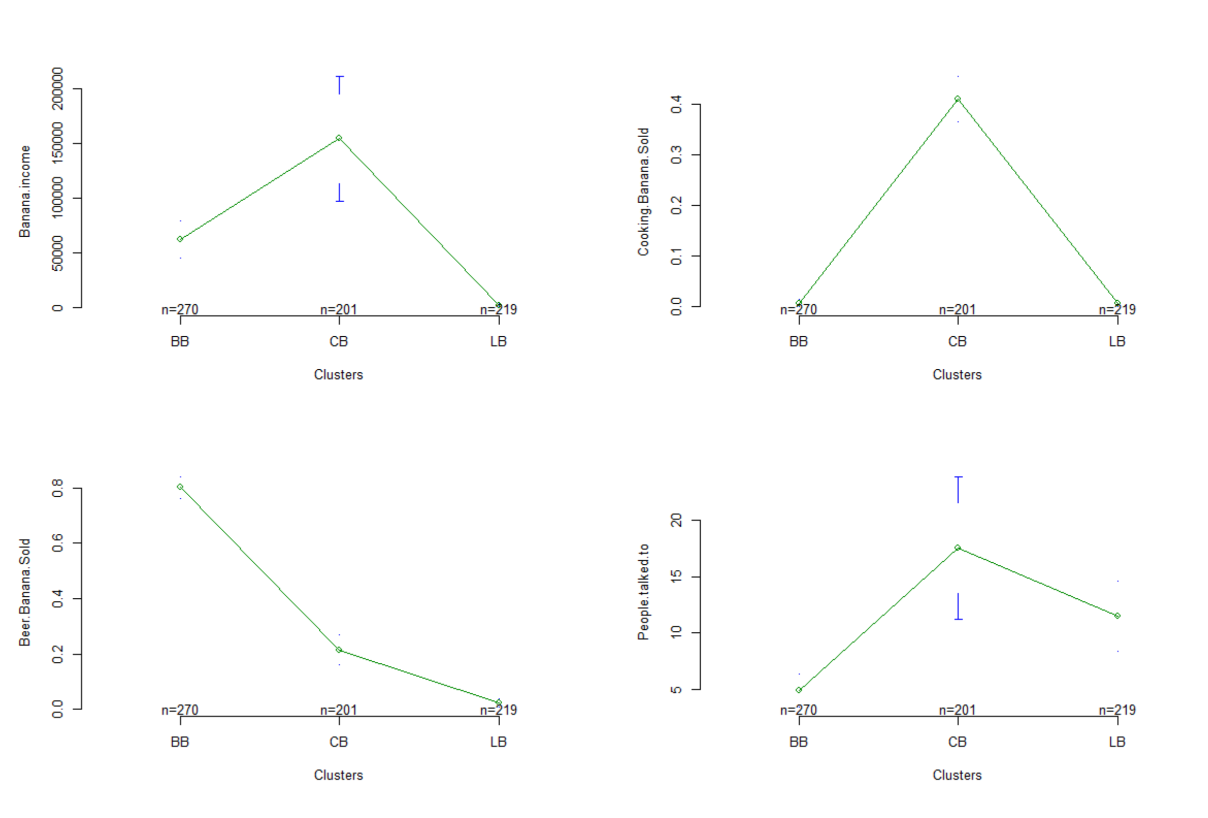


Figure 37: Characteristics of household and respondent by banana farm clusters

Implications of farmer typology for ICT use

In results presented in table 3 and 4 cooking banana farmers are used as reference in the logistic regression analysis. Results presented in table 3 show that cooking banana farmers are more likely to own both smart and basic phones. Beer banana farmers had significant decreasing likelihood of owning and use mobile phone both smart and basic compared to cooking banana farmers. Furthermore beer banana farmers had also more than two times higher likelihood of not having mobile phones. Although livestock banana farmers had a dicreasing likelihood about owning and using both smart and basic mobile phones this was not significant compared to cooking banana farmers.

Table 3: Regression analysis results about clusters ownership and use of mobile phones

Response variable	Predictor variable	Coefficient	S.E.	p-value	Odds ratio
Own smart phone	Banana grower cluster			0.059	
	Beer BF	-1.0	0.5	0.044*	0.4
	Livestock BF	-1.0	0.5	0.065	0.4
	Constant	-2.8	0.3	0.000***	0.1
Own basic phone	Banana grower cluster			0.001***	
	Beer BF	-0.7	0.2	0.001***	0.5
	Livestock BF	-0.2	0.2	0.314	0.8
	Constant	1.3	0.2	0.000***	3.7
Does not own a phone	Banana grower cluster			0.001***	
	Beer BF	0.8	0.2	0.000***	2.3
	Livestock BF	0.4	0.2	0.132	1.4
	Constant	-1.4	0.2	0.000***	0.2
Used smartphone	Banana grower cluster			0.009**	
	Beer BF	-1.6	0.6	0.005**	0.2
	Livestock BF	-1.0	0.5	0.050	0.4
	Constant	-2.6	0.3	0.000***	0.1
Used basic phone	Banana grower cluster			0.001***	
	Beer BF	-0.8	0.2	0.001***	0.4
	Livestock BF	-0.3	0.3	0.279	0.7
	Constant	1.8	0.2	0.000***	6.2

Key: *BF= Banana farmers, S.E=Sandard error*

ICT use barriers

Results presented in table 4 show that cooking banana farmers had no significant particular barriers in the provided list however they are more likely to face other challenges which include the fact that ICT-based tools are expensive, language barriers, etc. Beer banana farmers are more likely to lack awareness of the existence of mobile based extension services than others and are also two times more likely to lack technical know how to use phone based extension services. Livestock banana farmers, though having positive likelihood of facing barriers such as awareness, availability and lack of technical Know how, these were not significant compared to cooking banana farmers.

Table 4: Regression analysis results about clusters ICT use barriers

Barriers to the use of ICT	Predictor variable	Coefficient	S.E.	p-value	Odds ratio
Awareness	Banana grower cluster			0.074	
	Beer BF	0.4	0.2	0.029*	1.5
	Livestock BF	0.1	0.2	0.544	1.1
	Constant	-0.1	0.1	0.438	0.9
Availability	Banana grower cluster			0.544	
	Beer BF	0.4	0.4	0.435	1.4
	Livestock BF	0.5	0.5	0.272	1.6
	Constant	-3.2	0.4	0.000***	0.0
Know how	Banana grower cluster			0.079	
	Beer BF	0.4	0.2	0.027*	1.5
	Livestock BF	0.2	0.2	0.361	1.2
	Constant	-0.8	0.2	0.000***	0.5
Time	Banana grower cluster			0.321	
	Beer BF	0.2	0.5	0.741	1.2
	Livestock BF	0.6	0.5	0.178	1.9
	Constant	-3.3	0.4	0.000***	0.0
Language	Banana grower cluster			0.743	
	Beer BF	-0.3	0.5	0.523	0.7
	Livestock BF	-0.4	0.5	0.495	0.7
	Constant	-3.1	0.3	0.000***	0.0
Literacy	Banana grower cluster			0.533	
	Beer BF	0.5	0.4	0.271	1.6
	Livestock BF	0.2	0.5	0.608	1.3
	Constant	-3.2	0.4	0.000***	0.0
Others	Banana grower cluster			0.026*	
	Beer BF	-0.7	0.2	0.007**	0.5
	Livestock BF	-0.4	0.2	0.125	0.7
	Constant	-1.2	0.2	0.000***	0.3

Key: *BF= Banana farmers, S.E=Sandard error*

The table 5, containing summary of descriptive statistics about farmer's perception about the use of ICT (Mobile based) BXW management practices information delivery, shows that majority of respondents, in all banana farm clusters, perceived the use ICT-based agricultural services as somewhat useful but beer banana farmers had big number of farmers perceiving the ICT-based agricultural services as irrelevant.

Table 5: Relevance of ICT for BXW management by clusters

ICT relevance Category	Beer BF(270)	Livestock BF(219)	Cooking BF(201)	χ2tests of independence
Neutral(79)	(40)14.8%	(30)13.7%	(9)4.5%	$\chi2(2)= 25.57^{**}$
Not useful(24)	(13)4.8%	(2)0.9%	(9)4.5%	
Somewhat un-useful (123)	(46)17%	(32)14.6%	(45)22.4%	
Somewhat useful(368)	(134)49.6%	(129)58.9 %	(105)52.2%	
Very useful(96)	(37)13.7%	(26)11.9%	(33)16.4%	

DISCUSSION

The use of ICT in agriculture is considered as a key pillar of Rwandan economic transformation towards middle income country (Lichtenstein, 2016). According to Salampasis and Theodoridis (2013) an ICT tool is defined an application or a device used to collect and exchange data through interaction or transmission. In this study we evaluated the potential of using phone based extension services for effective BXW management. From this reason we analyzed baseline study survey data to understand how ready farmers are in this regard. In addition to this, to facilitate effective intervention tailoring, we considered farm heterogeneities by grouping them into clusters of similar socio-economic characteristics. It has been discussed that the limited adoption of innovation is probably associated by using a one-size-fits-all model (Coe et al., 2016; Hammond et al., 2017).

The PCA identified 12 variables responsible for banana farmers' heterogeneity which were used in farm clustering. The identified farm clusters, zooming in the main focus of farm banana production system, seemed to be appropriate and meaningful in Rwandan banana farming system. The main focus of first cluster (BBF) is the beer banana which is allocated to a large portion of banana land, the second cluster (LBF) main focus is livestock whereas the third cluster (CBF) main focus is cooking banana also allocated to a large portion of banana land. As discussed by Bidogeza et al. (2009) results from clustering must be clear and realistic to represent the empirical situation. Several studies emphasized that clustering individuals in more similar characteristics group is a potential entry point to diffusion of innovation and uptake since this probably results in almost similar behaviors (Bidogeza et al., 2009; Blazy et al., 2009; Barnes et al., 2011; Hammond et al., 2017). With results of this study we believe that the main focus of a farm cluster is also the priority of that farm thus any intervention plan should take this into account. For example, in the context of BXW prevention and control, animals have significant implications (Nankinga and Okasaai, 2006; Tinzaara et al., 2011). In this regards BXW interventions design for livestock based farmers should consider that the group might consider that animals are more important than banana. In line with arguments of Janssen et al. (2017) that for the community to benefit from ICT based model they should be involved in co-development to cover priority needs of beneficiaries, we argue that developing a phone based application to manage BXW in banana production system, for example, should consider to include in some ways livestock management options for the sake of livestock based farmers. This support the theory of diffusion of innovations by Rogers (2003) mostly the point that innovation is quickly adopted when it fits in the existing social values and practices.

Concerning banana farm clusters owning and using mobile phone, the different groups have varying likelihood to own and use mobile devices. The cooking banana farmers seemed to be better-off in view of banana income possibly reason why they are more likely to own and use mobile phones. This is in agreement with the study by Tadesse and Bahiigwa (2015) who studied the impact of using mobile phones in agricultural marketing in Ethiopia. Majority of farmers had basic type of mobile phones which has implications on the potential of using agricultural mobile application as most of applications are designed to be used in smart phones. The study by Tadesse and Bahiigwa (2015) identified age and education level as significant determinants of owning and using a mobile phone where younger are more likely to own and use the phone and higher education increases the probability. This is in slight agreement with our findings since the average age of beer banana farmers who are less likely to own and use phones is high and the cooking banana farmers who are more likely to own and use phones had higher education level compared to other group of farmers. In regards of McCampbell et al. (2018) review suggesting four pathways of using ICT (Mobile phone) based extension services to prevent BXW occurrence we assume that smart phone owners, in the case of this study cooking banana farmers, have a lot more ways to provide information back, but for normal phone users (Beer banana farmers) this use is limited. However there are also a number of ways that basic phones can be used to provide farmers with information and learning tools such as SMS and voice based. From this respect cooking banana farmers and livestock banana farmers are more likely to be open for providing data for prevention and sharing/receiving technical information for control whereas beer banana farmers can also be connected for connective actions.

The main challenge of the use of ICT (Mobile phone) based extension services was lack awareness of the existence of such services and the limited technical know-how. This implies that the release of mobile based application will requires sensitization for raising awareness especially to beer banana farmers who are more likely to face these challenges than the rest of banana farmers groups. Awareness, technical know-how and availability of services are important variables that influence adoption, perception and use of ICT based solutions.

CONCLUSION AND RECOMMENDATIONS

Results show that cooking banana farmers are more likely to have and use mobile phones both smarts and basics than other banana growers' clusters. Beer banana farmers have higher likelihood of not having a phone and have big number of farmers perceiving the ICT for BXW management as irrelevant. The use of ICT is limited by lack of awareness and lack of technical knowhow in beer banana farmers whereas cooking banana farmers are limited by other challenges such as being expensive. The studied farmers provide potential for using ICT (Mobile based) extension services however beer banana farmers, less likely to own smart phones, are limited to few options. We conclude that the use and perception of phone based extension delivery is differentiated by banana production system described as farm clusters in this study and major barriers to "use and perception of phone based extension services" is associated with limited access and linkage to extension delivery system. We thus recommend the consideration of heterogeneity of banana growers when designing and deploying ICT based technologies to prevent and control BXW.

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IS FARMING TECHNOLOGY INNOVATION LOCUS DEPENDENT? MAKING-OF AN AGRICULTURAL FABLAB

Davide Rizzo[a,b], Anne Combaud[a], Nathalie Schnuriger[c], Fatma Fourati-Jamoussi[a], Simon Ritz[b], Valérie Leroux[a]

[a] InTerACT Research Unit UP 2018.C102, Institut Polytechnique UniLaSalle, France
[b] Chair in Agricultural Machinery and New Technologies, Institut Polytechnique UniLaSalle, France
[c] Institut Polytechnique UniLaSalle, France

Abstract

Innovation has multiple targets – products, production processes, marketing, stakeholders' organizations, etc. – whose nature depends upon the socio-technical framework that orients the match between inventions and market. Amid the wealth of options to facilitate innovation, fablabs are a specific example of the digitalisation era. Originally, a fablab is "the educational outreach component of MIT's Center for Bits and Atoms" whose identity is defined by a charter that connects local labs to the global network. Fablabs' goal is to provide stimulus for local entrepreneurship as well as for learning and innovation by providing access to tools for digital fabrication. This paper aims at understanding the role of fablabs and other third places in the specific context of farming technology innovation. To this end, we propose a genetic-like analysis (i.e. genotype x environment x management practices), by addressing the historical identity and traits of FTI actors, the description of the main characteristics and dynamics of the place where they are based and the innovation governance put in practice to enhance their interactions. The approach was applied at two levels: first, the main actors of the farming technology innovation in Europe, ending with a bibliometric analysis of the available literature about fablabs, makerspaces and living labs, with a focus on agriculture. Then, a case study from northern France to describe the making of AgriLab, a fablab dedicated to open innovation towards sustainable agriculture, spanning from equipment to digital tools. AgriLab is based in Beauvais (Hauts-de-France region), together with several other local and international actors of farming technology innovation. In conclusion, we question the role of third places and AgriLab as catalysts for the emergence of relevant farming technology innovations considering the influence from the local and wider context.

Introduction

Innovation is a novelty introduced within an established arrangement, according to the Latin etymology. Accordingly, the farming technology innovation (FTI hereafter) could be referred to the novelties introduced in some of the established ways of farming, namely concerning the tools mobilised to accomplish agricultural practices. Of notice, we adopt here a wide concept of innovation, which embraces novelties in production assets, production processes, products, marketing, stakeholders' organization and so forth.

Our main question is: how are farmers involved in FTI? The underpinning hypothesis is that future FTI needs to identify approaches to empower farmers innovation capabilities within the farming 4.0 ecosystem (Dubois et al., 2019). We adopted a broadly interpretivist approach inspired by a genetic-like framework, where the observed features are considered as a result of the interaction between genotype x environment x management practices. This metaphor was meant to address the interactions between the history of involved actors (the genotype) and their place-related features (the environment) as a way for evaluating and orienting the innovation governance (management practices). In this vein, we stressed the role of support space (the locus) in forging the innovation system. Of notice, we consider that actors' location is a key factor in orienting FTI because of the place-based nature of agriculture.

Indeed, agriculture is by its nature deeply related to the given agronomical and pedoclimatic context where it is operated (van Ittersum and Rabbinge, 1997). In this sense, farmers are entrepreneurs whose knowledge is rooted in the daily management decisions about crop and animal husbandry. In the progress from the second to the third agricultural revolution, farmers benefited of a greater technology transfer from research and industrial development; yet, they became more dependent from external actors for the provision of productions assets like genetic improvement, phytochemicals and mechanics. Digitalization is at the origin of a fourth revolution in agriculture by adding a non-tangible dimension to the production assets. In the "farming 4.0", or augmented agriculture, a brand-new cyber-physical frontier can be used to extract data and information from farmers' practices and the agricultural production system (Lioutas et al., 2019), finally allowing a knowledge intensive agriculture.

The aim of this paper is to describe the making of a fablab explicitly oriented to farmers, called AgriLab emerged within an agricultural socio-technical system in northern France. We applied the interpretative framework to two embedded levels of FTI. In the first section we address the agricultural digital transition in Europe; in the second section we focus on northern France, as one of the regions with the highest arable land ratio within the first European country for agricultural production (Agreste, 2018). In particular, we explored how the anchorage of an agtech cluster within a field crop farming system region could enhance farmers involvement in FTI. Each section is structured in three parts: (1) identification and brief history – the *genotype* – of the main FTI actors; (2) highlight of the context and place (i.e., *locus*) dependent features, interpreted as the effect of the *environment*; (3) emergence of third places in the FTI governance, interpreted as the *management practices* that could help understanding the expression of locus dependent features.

Third places indicate hereby the physical spaces where new product development can take place. Their specificity is being sites (i.e., *loci*) emerged to meet the expectations of heterogeneous actors towards emancipation and community empowerment (Rosa et al., 2017). Generally identified as places for the "maker movement", they can also emerge to enable creativity within established corporate actors thanks to the reset of organizational boundaries (Fuller and David, 2017). Our focus will be on fablabs and maker spaces, as the wider context of emergence of two agricultural specific third places, like FarmHack in the USA and Atelier Paysan in France.

Altogether, the descriptions will set up the background to analyse the emergence of an agricultural fablab as a third place between farmers and the others actors involved in the FTI. In conclusion, we propose some considerations about the levers to enable the role of AgriLab as catalyst in the emergence of relevant (digital) technologies for sustainable agriculture within the agricultural innovation ecosystem.

First level: FTI within agricultural digital transition in Europe

In a world perspective, European agriculture is characterized by great attention to precision and data augmented agriculture (Kritikos, 2017; Schulze-Lammers et al., 2016). As such, the equipment sector being reshaped by the arrival of many newcomers and agtech provides that are external both to the manufacturer and the agricultural domain (Rizzo et al., under review). For the first level of description of the FTI, we focused on European actors of the crop production, the farming 4.0 context and a rapid overview of innovation governance through fablabs and similar "third places".

Main actors of FTI in Europe (genotype)

Mechanization is one of the drivers of the third agricultural revolution, being so far an important arena for the emergence and development of FTI. The agricultural machinery sector is composed by manufacturers, dealers and the different users, including farmers, their groups and cooperatives as well as contractors (Rizzo et al., under review).

Machinery manufacturers include the constructors of machines (e.g., tractors, seeders, harvesters), and tools (e.g., ploughs, harrows) that can be used for realizing farming practices. They have historically evolved from blacksmith workshops, gradually joined with the availability of mechanical engines. As such, these manufacturers master metals and materials needed for the manufacturing, as well as the practical skills to shape tools suited for farming. Manufacturers include different sizes and profiles of enterprises, from the small and medium ones, frequently specialised in a few types of equipment, up to large enterprises, for the most correspondent to international groups that produce all the equipment needed from the soil preparation to harvesting. Manufacturers pointed-out the weakening of the interfaces with the end-users, namely the farmers, because of the decrease in the number of farms so of clients (Dryancour, 2016). Moreover, the digitalization and shift towards augmented agriculture widened the concept and development of equipment, eventually including embedded sensors and electronic connection on-board. This resulted in the emergence of new actors, either as technology or machine provides, such in the case of ISOBUS and agricultural robots.

Dealers. The growing specialization and outreach of the machinery market needed the organization of distribution and selling. As so, the machinery dealers represent for manufacturers the real interface with final users. The restructuration of the machinery sector due to the reduction in the number of farmers is stressing the competition between brands and associated dealers (Dryancour, 2016). This results in a profound revision of the distribution strategy, leading on the one hand to merging selling points and on the other hand to the differentiation of services. In particular, the dealers claim a role in the development and provision of new data-related services for the farmers (CLIMMAR, 2018), which are on their side relying on dealers to be supported in the choice of agtech. A survey carried out in 2019 in France involving 952 farmers and 112 contractors showed that 3 respondents out of 4 believe that dealers will be the best actors to buy agtech from (Enquête Datagri, 2019).

Farmers represented roughly 4.4% of the working population across the European Union in 2015, accounting for 10 million people (Eurostat, 2017). They are organised in the Copa-Cogeca group of interest. In a recent document, they wrote in their strategy the call to facilitate the technological uptake through training and advisory services; also, they stressed the belief in farmer-led agri-tech revolution and the role of cooperatives for driving the digital transformation of the sector (Copa-Cogeca, 2019).

FTI under farming 4.0 (environment)

The increasing number of connected devices and embedded sensors are allowing for the digitalization of physical variables, as well as to tracking farmers' actions. Altogether, the availability of a growing amount of very diverse data, together with the progress of computational capabilities, is enabling the development of advanced algorithm capable to extract relevant knowledge from complex systems. Devices, data and computational capabilities are eventually paving the way for new deep insights in farmers' decision-making process. In summary, where the third agricultural revolution reduced the farmers' mastery of production assets, the fourth one could increase the dependence of farmers from external actors, namely the digitalization players, up to the extraction of farmers' tacit knowledge codified in algorithms and decision support systems (Dubois et al., 2019).

In this perspective, we argue the risk for FTI to leave farmers apart from the definition of relevant novelties for their entrepreneurial activities. Insofar, a rich literature addressed the adoption of FTI by farmers, eventually considering them as the passive recipients of accomplished solutions. A different perspective could emerge if looking at the reasons of the actual use of FTI, such as precision farming techniques. A pioneering study about how technologies were used by adopters pointed-out the need for local references to evaluate the on-farm relevance of such innovations (Ayerdi Gotor et al., 2019). Furthermore, the non-tangibility that characterizes the digital components of the farming 4.0 FTI raises questions about knowledge disparities and trust among actors (InPACT, 2016; Jakku et al., 2018).

Third places for innovation governance (management)

The maker movement is resulting in the emergence of dedicates places, which take different names according to the way the community is ruled. We performed a bibliometric analysis to set the scene about the three most accepted definitions of third places: fablabs, makerspaces and living labs. To this end, we retrieved three corpora on the Scopus database (Table 21). The results were heterogeneous both for the number of retrieved items and for the covered period, probably because of the level of specificity of each definition and for its age of use (Figure 38). On the one hand, living lab appears to be the most generic and long used of the three, even though only a few items were retrieved before 2004. On the other hand, fablab and makerspace could have a partial, though limited, overlap; the latter definition emerged in the scientific literature probably as more generic version of the MIT version and related to the Maker Faire concept as social event to gather together different "makers" (Rosa et al., 2017).

Table 21. Constitution of the corpora for the bibliometric analysis of fablab and maker space literature.

Corpus [a]	Search string [c]	Nb of items	Period
FL – fablab [b]	(TITLE-ABS-KEY (fablab*) OR TITLE-ABS-KEY ("fab lab")) AND PUBYEAR > 2001	312	2004-2020
MS – makerspace	(TITLE-ABS-KEY (makerspace*)) OR (TITLE-ABS-KEY ("maker space"))	598	2010-2020
FL-MS (items mentioning both)	((TITLE-ABS-KEY (fablab*) OR TITLE-ABS-KEY ("fablab")) AND PUBYEAR > 2001) AND ((TITLE-ABS-KEY (makerspace*)) OR (TITLE-ABS-KEY ("maker space")))	65	2012-2019
LL – living lab	(TITLE-ABS-KEY (livinglab*)) OR (TITLE-ABS-KEY ("living lab"))	1413	1990-2020

[a] research performed on November 3rd, 2019 on the Scopus database in title, abstract and keywords
[b] the research aimed at simple and plural occurrences of the search terms
[c] the first Fablab was established by MIT in 2002, so the research was limited to paper after 2001.

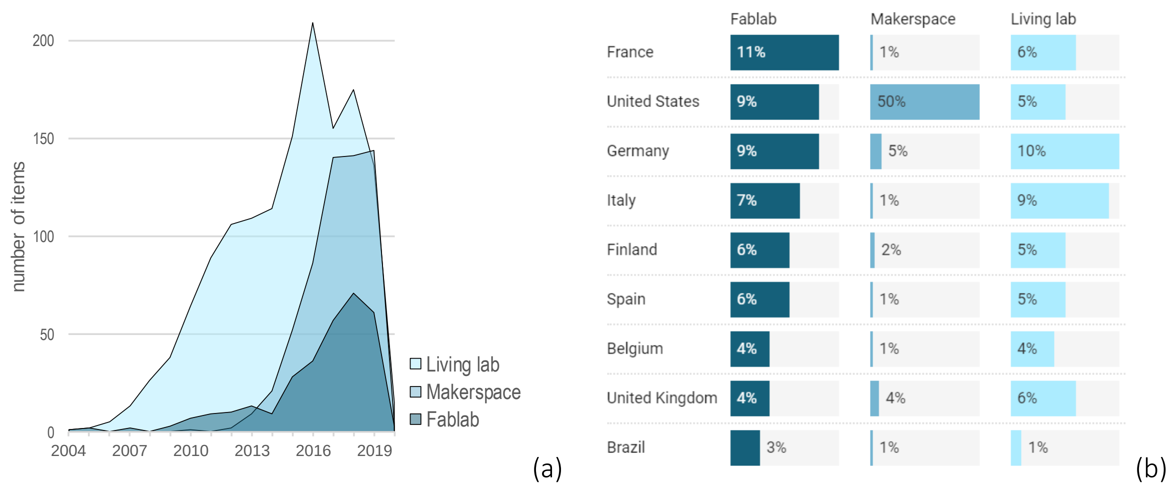

Figure 38. Quantitative description of the three corpora: fablab, makerspace and living lab. (a) number of published item per year, subset from 2004 to 2020; (b) distribution of affiliation countries, percentage on the total number of affiliations per corpus, subset oft he 9 top countries for fablab literature (source: elaboration on Scopus corpora).

Living lab overall idea is credited to the early 2000s by the Massachusetts Institute of Technology. The scientific literature about living lab is continuously growing from 2006 (Figure 38, a), year of publication of the Helsinki Manifesto. It was issued from a conference that "proposed renewal of the European innovation system to create a new open, user-centric and networked innovation environment in Europe" (Finland's EU Presidency, 2006) The same conference led to the creation of the European Network of Living Labs as the international federation of benchmarked Living Labs in Europe and worldwide. The year 2016 marked an important step in this network with 7 new approved EU projects and 7 that were successfully concluded (ENoLL, 2018). Altogether, living lab identified an approach to open innovation focused on citizens involvement and a focus on public-private partnerships, eventually allowing for a better understanding and elicitation of the ontology of the needs (Dutilleul et al., 2010). As such, living lab embraces also more defined approach such as fablabs and makerspaces and the like (Givone et al., 2015).

Amid the wealth of options to facilitate innovation and living lab forms, fablabs are a specific example of the digitalisation era, which is focused on the connection between bits and atoms. Indeed, fablab (shorter for Fabrication Laboratories) is "the educational outreach component of MIT's Center for Bits and Atoms" whose identity is defined by a charter that connects local labs to the global network. Complying with the Fab Charter (CBA, 2012) is a distinctive feature of fablabs, which should provide a core selection of hardware and software capabilities allowing to reproduce projects across the community network (Rosa et al., 2017). Fablabs' goal is to provide stimulus for local entrepreneurship as well as for learning and innovation by providing access to tools for digital fabrication. The retrieved literature about fablab appears to be lower than the other two corpora, though revitalized after 2016 (Figure 38, a).

Makerspaces are grassroots "community centres with tools" (Gui Cavalcanti, 2013) framed within the do-it-yourself and maker movement, in large parts oriented by pragmatism and a continuous problem-driven exchange within the community (Voigt et al., 2016). Makerspace definition stemmed out of the hacker community (Marusteru, 2017), yet clearly defined only on 2013 for a workshop called "How To Make A Makerspace" (Artisan's Asylum and MAKE, 2013). This concept showed then a steady increase in the literature (Figure 38, a).

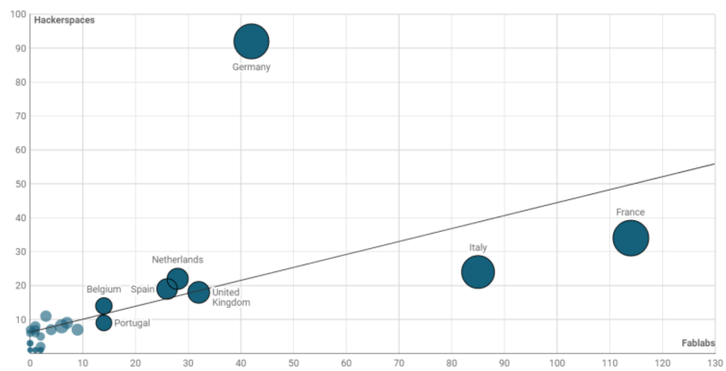

Figure 39. Number of makerspaces in Europe, according to their type. Adapted from the survey by Rosa et al. (2017). Dot size is proportional to the total number of spaces, including fablabs, hackerspaces and other types (the latter are not shown). The trend line separates countries according to the dominant type of space: hackerspaces in the upper half, fablabs in the lower half.

The three corpora showed a clear territorial anchorage, with publications about fablabs coming chiefly from researchers affiliated in France (11% of the total affiliations of this corpus), makerspaces from the United States (50% of the corpus) and living lab from Germany and other European countries (Figure 38, b). This could suggest a linguistic differentiation in reference to similar approaches and concepts that is consistent with the trends in Google search (Voigt et al., 2016)[101]. A recent European report surveyed fablabs, hackerspaces and other types of what they called collectively "makerspaces", showing that France, Germany and Italy have the greatest number of these spaces, yet with a different distribution (Figure 39).

[101] Cf. https://trends.google.com/trends/explore?date=all&q=makerspace,fab%20lab,hackerspace,living%20lab

The corpora were analysed with the CorText platform (http://www.cortext.net) to get a rapid simple overview of the key terms, the structuring topics and the interest per Country (i.e., the affiliation country of the authors of the retrieved item). We processed the corpora to extract the terms through a text mining script operating a natural language processing. This allowed us to go beyond the too synthetic topic description provided through author keywords, by including also title and abstract per each retrieved item.

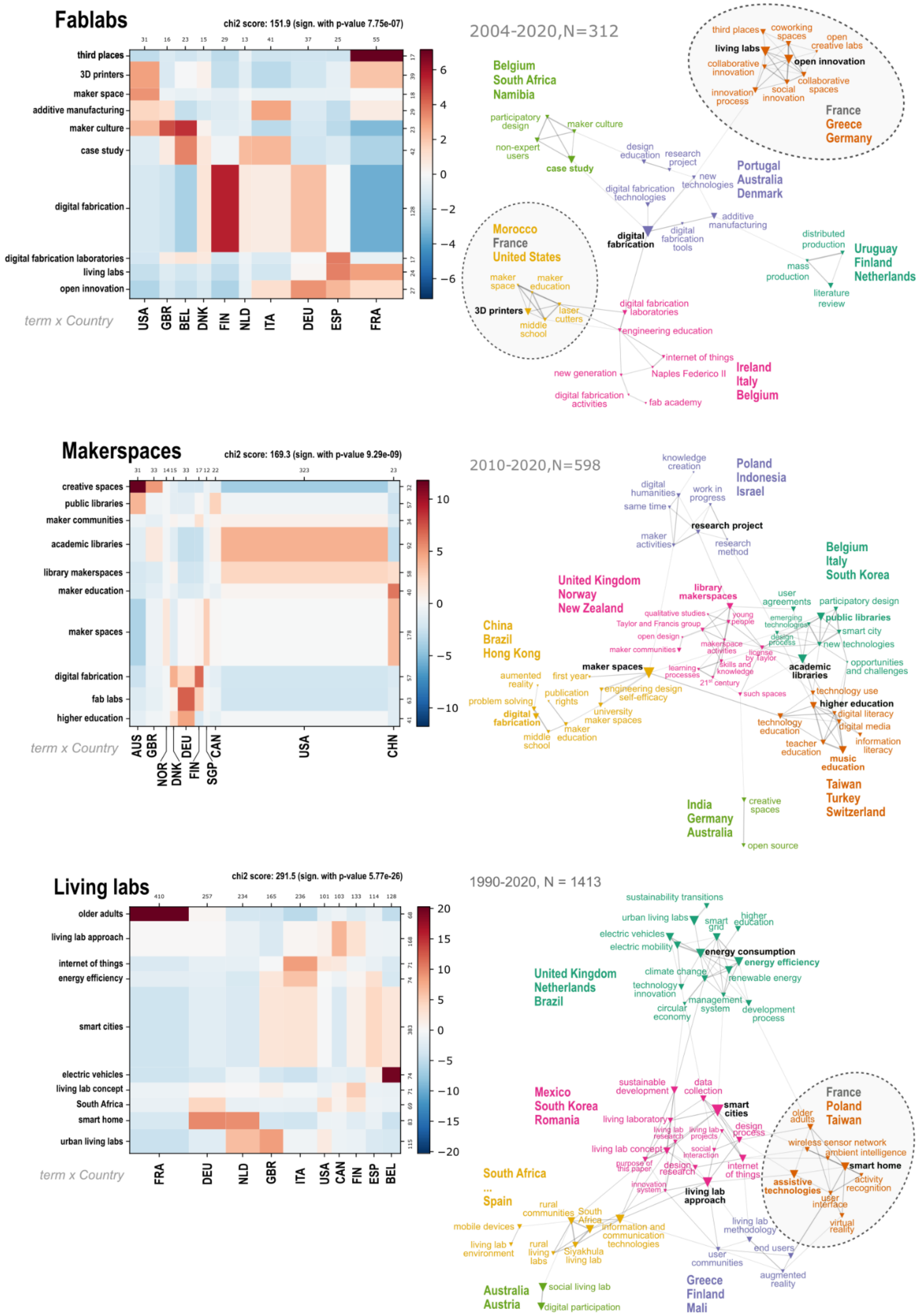

Figure 40. Bibliometric analysis of terms and Countries of researchers' affiliation. (left) Contingency matrix showing the degree of correlation between the 10 top pairs of term-Country. The size of the squares is proportional to the term frequency in the database. Cell colour refers to the significance of

the correlation, red for the most correlated (co-occurrence higher than expected), blue for the anti-correlated (co-occurrence lower than expected), while the intensity of the colour represents the chi2 score of relevance. (right) Terms co-occurrence base on the top 50 nodes. The triangles represent individual terms and their size is based on the number of co-occurrences. Colours of the triangles identify clusters of co-occurrent terms, then labelled by the authors' affiliation country, with proximity meaning terms mention by authors whose affiliation is in the same countries (France in shaded circles).

The script for term extraction follows 5 steps: identification of the part of the speech (noun, adjective, verb, etc.), chinking to build possible multi-terms (e.g., a list of successive nouns), normalization to smooth minimal orthographical differences (e.g., grouping of hyphenated and non-hyphenated forms), stemming to group terms that share the same root, then counting (Cortext team, 2016). Based on the extracted terms, we performed two analyses: (1) *contingency matrix* to compare the frequency of term per Country; (2) *term co-occurrence* graph to map proximity between terms, then clustered and labelled by country (Figure 40).

Concerning fablabs, the results highlighted a significant positive occurrence of the terms "third places" and "living labs" in the documents by French researchers, who are less inclined at referring to "digital fabrication" and "maker culture". The latter are more frequently used, respectively by Finnish or Belgian researchers, who appeared oriented also towards distributed production, internet of things and fab academy. Makerspace literature resulted in a more compact configuration as it is more recent. Of notice, researchers from Australia emphasized the association with "creative spaces", whereas Germany and Finland were more oriented to fablabs and, again, digital fabrication. In conclusion, living labs were chiefly associated to older adults by French researcher and electric vehicles from Belgian (Figure 40).

In this rapidly evolving landscape, the European Union drew a first census of makerspaces (including though hackerspaces and fablabs), counting a few hundred of different spaces, for the most located in France (158, 114 of which fablabs), Germany and Italy (Rosa et al., 2017). Some of them can declare a thematic orientation, for instance to reduce concurrence in areas where multiple close communities coexist; though, the basic idea is that the identity of these labs and spaces is foremost defined by the community and not simply as physical equipped sites. Indeed, only few if none of the labs or spaces is specifically dedicated to agriculture. Some of the reasons can be the anchorage within city-based communities and the lack of space. Agriculture is therefore addressed as urban agriculture, even though a few exceptions exist. FarmHack and Atelier Paysan are among the oldest. Farm Hack was founded in 2010. It is an on-line and in-person community of farmers, engineers, and technologists working to make farm tools and equipment more accessible, adaptable, and appropriate to small and medium scale sustainable agriculture systems (Cox and Grover, 2015). Atelier paysan is a French community that presents itself as a cooperative for auto-construction of agricultural equipment, formalized in 2011. They stress the farmers' capability to invent the tools needed for farming. Both of these communities foster to put full control over the means of production into the hands of farmers as a mean to empower peasants and pursue sovereignty for collective food security (Pimbert, 2017).

Second level: FTI in the case study (Beauvais, northern France)

For the second level, we focused on France and the FTI actors located in Haut-de-France region (northern France), with a focus on the Beauvais area for its concentration of FTI actors (Rizzo et al., 2018). In particular, we stressed the history of the actors involved in the development of agricultural machinery and software, as well as in education. The choice of the regional and local administrative bodies to enhancing connections and alignment between actors in innovation systems by strengthening the public/private/people partnership (cf. Hermans et al., 2019). We analyze here the results of major local innovation governance measures that led to the emergence of third places both within the enterprises, the academy and independent (for this classification, cf. Bouquin et al., 2016), as well as new actors. The main question is the explicit involvement of farmers as actors in FTI.

Local actors of FTI: history and interactions (genotype)

(1854) Institut Polytechnique UniLaSalle. It is a higher education institute that proposes, on Beauvais campus, short programs and degrees in agriculture, geology and food and health (www.unilasalle.fr). In its earlier form, it dates back to 1854 as section in the local school for teachers. Since the earlier years, founders fostered the relation practice-theory-practice and addressed the synergies between agricultural and industrial sectors as main drivers of the national development. Accordingly, the educational program included the purchase of a farm and the creation of experimental stations, and it is nowadays strongly committed to the integration of sustainability in the educational programs (Fourati-Jamoussi et al., 2018). Throughout its history, two societies of software development stemmed out: (i) ESCORT, based on a study office created in 1969; (ii) ISAGRI, created as a spin-off in 1983 (see below).

(1960) AGCO. Massey-Ferguson sided its production sites of Banner-Lane in Coventry with a new plant in Beauvais, where the tractor produced in Saint-Dizier were assembled. This manufacturer was the third in Europe, and the third in the world since the acquisition by the AGCO in 1994. The Coventry site that was dismissed in 2003 was the largest tractor manufacturer facility in the western world. The move to northern France was initially justified by the lower operational costs, then confirmed for the location within a well-known agricultural production context (Bienfait, 1959). As such, the site continues to develop the territorial anchorage (Desindes, 2012): three additional production sites have been implanted in Beauvais, the fourth having been bought in 2019. Leader for standard tractor production in France, Massey-Ferguson Beauvais is the most important AGCO production facility in Europe (Jouan and Paturel, 2019). By the way, AGCO started interactions with UniLaSalle, by becoming a partner for the provision of tractors and combine to its farm, and lately, a supporter of the Chair in agricultural machinery (see below). Also, its current vice president & managing director for Europe and the Middle East, Thierry Lhotte, is an UniLaSalle alumni.

(1994) Groupement International De Mecanique Agricole - GIMA. In 1994, Massey Ferguson created, before its integration in AGCO group, GIMA, a joint venture (60:40) with Renault agriculture, later become CLAAS tractor. The goal is to develop and produce transaxles systems for agricultural application. GIMA is an important asset to strengthen the industrial development of Massey-Ferguson.

(1983) Groupe-ISA. The group consists of ISAGRI, Irium Software and Nouvelle génération de presse agricole. Irium SOFTWARE is the European leader of Enterprise Resource Planning for agricultural machinery (dealers, rentals, importers...). Nouvelle génération de presse agricole is a media group, leader in the agricultural field, included printed press, website and a society of analysis and understanding of farmers' behaviors and expectations. ISAGRI is a European leader in the development of computer-based tools for farm management. It was created by a teacher of the Agricultural Engineer School of Beauvais, Jean-Marie Savalle, current CEO, and a few colleagues. In 1995 they left the school buildings where the spin-off was born yet remaining in the neighbouring area to keep the proximity and ease the students' recruitment. Every year, ISAGRI organizes a vocational training week for its employees on the UniLaSalle Beauvais campus. In 2019, ISAGRI signed a convention on disability with UniLaSalle in 2019 to facilitate the inclusion of students with disabilities

Cumulatively, in 2017 these actors employ almost 3,500 people (i.e., UniLaSalle 250, AGCO 1500, GIMA 1000, Groupe-ISA headquarter 700) in addition to 2000 UniLaSalle students, within an agglomeration of about 95,600 inhabitants.

FTI within a local agtech cluster (environment)

In a recent report, FAO pointed-out the risk that the application and dissemination of technologies could aggravate disparities (2017, p. 55), namely between high-income countries providing such technologies and recipient countries. Yet, disparities and farming technology divides can emerge also within western countries. For instance, a group of French farmers highlighted that acquisition costs are determining disparities in the FTI uptake because they can be met only by higher-income farming systems. On top of that, few adopters imply eventually their isolation and lack of nearby references to master these technologies that are, for the most, exogenous to agriculture (InPACT, 2016).

Agriculture is generally considered as a structural asset and as such its development is supported by dedicated policies and subventions. Indeed, the orientation of private investment in the sustainable development of agriculture depends on the policies and regulatory frameworks as well as on more general public investments in infrastructure and R&D (FAO, 2017, p. 129). Where the state cannot though directly change the strategies of FTI providers, such as in western countries, intermediary actors financed in part by public funds emerge to orient the FTI strategy. In this framework, the public sector seems more to play a catalytic role.

The environment appeared to be crucial in FTI for our case study. Regional strategic actions for FTI started in 2014, a year before the territorial reform that created the Haut-de-France by the merger between Picardie and Nord-Pas-de-Calais. In its Smart Specialisation Strategy (S3-2014-2020) the former Picardie region pinpointed societal pressure on sustainable agriculture, resulting in new needs for agricultural machinery and agronomic innovations. As such, the region decided to strengthen the regional dynamic around the agricultural machinery and precision agriculture on six axes (Région Picardie, 2014):

increasing the visibility of regional skills to encourage rapprochements between industries and R&D actors;

making the agricultural machinery industrial activities known to the regional mechanic industry, to involve convenience subcontracting;

supporting innovation;

supporting the establishment of supply chains for first transformation industrial sites;

accompanying companies abroad;

developing and adapting training schemes.

The Beauvaisis agglomeration provided continuity of this strategy within the new Hauts-de-France region by eliciting and supporting the creation of specialized intermediary organizations, targeted at playing a mediating role between the private industrial sector, higher education and farmers. It identified the UniLaSalle campus as a pivot in its territorial development strategy on the agtech sector because of the institute long commitment to education in FTI and its geographical and knowledge proximity to farmers. On the one hand, the Beuvaisis agglomeration branded the area near the campus as “technology park” dedicated to the establishment of actors of the innovation in the agfood sector. On the other hand, the agglomeration promoted the creation of intermediary actors and third places, thus convergenging with a more general trend for demand-driven agricultural research (Klerkx and Leeuwis, 2009). All this was institutionalized by the creation of a public-private cluster promoting the interactions of local FTI actors called Rev’Agro (Rizzo et al., under preparation)

Emergence of (open) labs and spaces to tackle FTI (management)

As for the first level of analysis, we want to observe here how innovation governance practices elicited the expression of relevant traits of local FTI actors. We specifically addressed the role of place dependent traits, *i.e.* the influence of the environment, as the main factor to evaluate the relevance of FTI strategic orientation management. In a context of structural mutations both for the agricultural machinery manufacturer, the regional cash crop farming systems and the agricultural higher education sector, the regional and local public authorities seem to have chosen to manage innovation through the creation of new places for private/public interactions. Of interest, private actors followed a private/private pathway for FTI. The common trait is the elicitation of interfaces with farmers, yet the relevance for actual farmers’ empowerment it is still unclear. Accordingly, this paper focuses on the making of AgriLab®, a fablab and living lab dedicated to open innovation towards sustainable agriculture, spanning from equipment to digital tools. By comparing AgriLab® creation with concomitant initiatives, we set the scene to understand its role as a catalyst for the actual involvement of farmers in local and wider FTI.

(2015) Chair in Agricultural Machinery and New Technologies – Chair AMNT. Promoted by the Region Hauts-de-France, also with funding by and the EFDR European program, the Chair is hosted by UniLaSalle with the patronage of AGCO, Kuhn and the Michelin Corporate Foundation. It fosters the design and development of research, education and training in agricultural equipment and new technologies to support the transition towards sustainable agrosystems (Rizzo et al., 2018) by acting at the interface between students, industry sector and farmers and their organizations (e.g., CUMA, cooperatives, and technical institutes).

(2018) AgriLab®. Co-financed by the Beauvaisis agglomeration, the Oise Department and the Region Hauts-de-France, AgriLab is an open innovation platform officially registered in the fablab worldwide network. It is one of the few fablab explicitly oriented towards agriculture and farmers. It is inspired by FTI group of practice and makerspaces such as Open Ecology and Atelier Paysan. Its novelty is to be completely oriented and equipped to support innovation by and for farmers and other stakeholders of the agrifood sector (Dantan et al., 2019). One should bear in mind that fablabs are communities before of being places. As such, they are more frequently related to city-based communities that are limited in available space, especially when ran on own funds. Hence, the agfood themes are generally tackled as urban agriculture, aquaponics or food processing. AgriLab instead is specifically addressed to the farmers' community; as such it is placed outside the city and close to arable farmlands. This was allowed by public-private investments for the creation of the buildings, and benefits also from the involvement of private actors for the running and community management. A few months after its opening, local agencies of Credit Agricole, world's largest cooperative financial institution, and CER France, leading association and consultancy network in France, committed with AgriLab territorial anchorage and wider development.

(2018) Promize. The locus dependence of FTI is less constraining when dealing with digitalization. The GROUPE-ISA followed nevertheless a pathway similar to the others by creating a start-up, called Promize, that fosters a better interface with farmers, dealers, advisers and the like. This third place, claiming itself as autonomous, is meant to promote agility and adaptation to partners, to create added value for various agricultural stakeholders, especially about digital FTI, such as IoT, bigdata, artificial intelligence, robotic and blockchain.

(2019) Farmr. Farmers are and claim to be actors of FTI. On the one hand, there are structural mutations in the regional cash crop farming systems, and more in general in western agriculture, due to the continuous reduction in the number of farmers and the increase in the education level and technological mastery of new and upcoming farmers (Rizzo et al., under review). On the other hand, farmers are getting more isolated, both for the increase in farm size in western and northern Europe and for the diversification and complexification of available and emerging farming technologies (McFarland, 2018). Digitalization and social media could therefore palliate at the lack of neighbour peers when farmers need to tackle FTI (Phillips et al., 2018). Two young entrepreneurs, one of which issued from a family of farmers, launched a network entirely dedicated and limited to farmers, called Farmr. First of its kind, this network allows farmers to exchange knowledge based on their situated expertise. It represents the most advanced specialization of other platforms to facilitate the farmer-to-farmer connections, yet being the only one that excludes other private actors.

(2019) Pim@tech. The structural mutations in the agricultural manufacturing sector led to the creation of private-private interfaces. French manufacturers are making important investments in infrastructures with an anticyclic scope (Jouan and Paturel, 2019, p. 3). In our case study, AGCO both invested to extend the production facilities in Beauvais and to reinforce the R&D assets. In line with the creation of GIMA in 1994, the current strategy was to foster the interface with the Technical Centre for Mechanical Industry (CETIM). The latter is the French most important technical centre for mechanical industry, whose goal is to improve companies' competitiveness through mechanical engineering, transfer of innovations and advanced manufacturing solutions. Supported by GIMA and AGCO-Massey Fergusson, the CETIM is the general contractor for a new international centre of innovation in agricultural machinery, Pim@tech, also supported by Regional funds and located on the Beauvaisis technology park.

Conclusion and perspectives

This paper addressed the question: FTI are locus dependent? The answer depends on the definition of locus. Farming is a locus (place) dependent activity, as it was the manufacturing of agricultural equipment. The development of farming technologies implies an innovation system because it involves multiple actors carrying specific skills (cf. Lundvall, 2016), thus the interaction between multiple loci. Furthermore, the digital revolution that impacts several production sectors, is leading FTI to increasingly creating cyber-physic interfaces. The resulting mix of tangible and non-tangible dimensions ends up questioning the original locus-dependency of FTI. Based on a two-level analysis (i.e., European and local level), we adopted the gene x environment x management metaphor to observe how these changes are inducing the expression of latent traits in the involved actors. The hypothesis was that the emergence of third places such as fablabs, makerspaces and living labs are tentative answers to manage FTI in the interactions between the historical traits of actors and their evolving farming 4.0 environment.

France shows the highest number of fablabs in Europe. A possible reason is the French fablab model, which includes both officially labelled communities (i.e., adopting the chart and being part of the world network) as well as other projects issued from institutional support to local groups committed with similar principles (Bouquin et al., 2016, pp. 20–21). We focused on AgriLab as a unique case of a third-place aimed at bridging again, though in a new way, the earlier actors of the FTI with the farmers. At the wider level, a similar trend could be observed for FarmHack and Atelier Paysan. Nevertheless, the latter appear to be farmer centred, whereas AgriLab is community centred, yet with a focus on farmers. In this sense, AgriLab is both enhancing the connection of farmers with the local community and empowering farmers in the FTI. As such, it participates to the sustainable development program of UniLaSalle. On the reverse, AgriLab could represent a mutation of the UniLaSalle genotype: this higher education institute was founded for training the trainers and evolved so far to educate new generations of farmers and agronomists. However, the FTI is accelerating the pace of emergence of technical novelties, which are increasingly shaped by the digital transition. As such, the ten-years that usually pass between the degree and the taking over the farm are becoming too long. In a certain way, AgriLab allows filling the gap by opening the training directly to the farmers, while also changing the way of producing and transferring knowledge.

In conclusion, the community centred production and sharing of knowledge that characterises fablabs, makerspaces and living labs has been challenged by the creation of an open innovation platform explicitly oriented towards agriculture and the farmers community. On the one hand, this can produce a mutation in higher education by strengthening the links between farmers and the learning community. On the other hand, the needs of a higher educational institute can produce a further mutation in the fablab approach, to consider place-based knowledge to feed sustainable FTI. In perspective, more research has to be done about the role of AgriLab in the local and wider context of public-private-people partnership and to understand which historical, environmental and management conditions are required to reproduce it elsewhere.

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Source Availability Statement: the public documentation about AgriLab® is on the dedicated collaborative platform and might be accessed from: http://agrilab.unilasalle.fr/

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SMART FARMING AND SHORT FOOD SUPPLY CHAINS: TWO DIAMETRICALLY OPPOSED ALTERNATIVES OR TWO SIDES OF THE SAME COIN?

Evagelos D. Lioutas [a], Chrysanthi Charatsari [b]

[a] TEI of Central Macedonia, Department of Supply Chain Management
[b] American Farm School of Thessaloniki

Abstract: Both smart farming and short food supply chain (SFSC) schemes are considered as promising alternatives to the conventional forms of producing and distributing agrifood products, having the potential to mitigate the environmental impacts of agriculture, to increase farmers' income and to produce new forms of value. Nevertheless, although smart farming has gained considerable momentum over the last few years, the integration of digital technologies and intelligent decision support systems in SFSCs has not yet been achieved. In this work, following a mixed research design, we aim at identifying farmers' and consumers' perceptions of and attitudes towards "smart SFSCs." Our results indicated that, although consumers who buy from SFSCs have a positive attitude towards smart technologies, they believe that their application in SFSCs will alter the unconventional character of short supply schemes. Such a "conventionalization" of SFSCs will lead to a change in farmer-consumer relationship, thus weakening the link connecting them. Farmers who participate in SFSCs express a mixed attitude towards smart farming since they perceive smart technologies as tools able to facilitate the achievement of higher efficiency but, on the other hand, they afraid that adoption of these technologies will create the need to restructure the modus operandi of farm enterprises. In both analyses, price and cost concerns were found to be important predictors of the general attitude towards smart SFSCs, but their contribution to predicting willingness to engage in smart SFSCs is limited. On the contrary, this (un)willingness is mainly driven by the symbolic content attributed to alternative food networks by both consumers and farmers. Qualitative findings confirmed that the major obstacle for the exploitation of smart technologies in SFSCs is their perceived incompatibility with the alternativeness of short supply schemes. For consumers, this incompatibility refers to the transgression of their imagery surrounding the concept of SFSCs, whereas for farmers it is associated with the need to redefine (once again) the meaning of farming. However, both samples were found to agree that the integration of smart technologies in SFSCs can increase the sustainability of short food supply schemes. Hence, smart technologies are viewed simultaneously as enablers of sustainability and as threats to the optimally distinct identity of SFSCs. In sum, these results reveal that smart SFSCs are conceived by both consumers and farmers as a Yin and Yang, combining seemingly opposite but potentially complementary paths towards sustainability.

HOW DIGITALISATION INTERACTS WITH ECOLOGISATION? PERSPECTIVES FROM ACTORS OF THE FRENCH AGRICULTURAL INNOVATION SYSTEM

Éléonore SCHNEBELIN [a], Pierre LABARTHE [b], Jean-Marc TOUZARD [c]

[a] UMR Innovation, DigitAg, Univ. Montpellier, INRAE, Institut Agro, Montpellier, France
[b] AGIR, Univ. Toulouse, INRAE, Castanet-Tolosan, France
[c] UMR Innovation, INRAE, University of Montpellier, 2 Place Viala, 34060, Montpellier, France

Abstract

Two major agricultural transformations are currently being promoted worldwide: digitalisation and ecologisation, that include different practices such as organic farming and sustainable intensification. In the literature and in societal debates, these two transformations are sometimes described as antagonistic and sometimes as convergent but are rarely studied together. Using an innovation system approach, this paper discusses how diverse ecologisation pathways grasp digitalisation in the French agricultural sector; and do not discriminate against organic farming. Based on interviews with key representatives of conventional agriculture, organic agriculture and organisations that promote or develop digital agriculture, we explore how these actors perceive and participate in digital development in agriculture. We show that although all the actors are interested and involved in digital development, behind this apparent convergence, organic and conventional actors perceive neither the same benefits nor the same risks and consequently do not implement the same innovation processes. We conclude that digitalisation has different meanings depending on the actors' paradigm, but that digital actors fail to perceive these differences. This difference in perception should be taken into account if digital development is to benefit all kinds of agriculture and not discriminate against organic farming and more widely, against agroecology.

Introduction

This paper deals with the relations between two major transformations of agriculture: ecologisation and digitalisation. Ecologisation is defined as "the growing importance of environmental issues within agricultural policies and practices" (Lamine, 2011; Lucas, 2021). Digitalisation refers to the increasing use of digital technology throughout the economy and society in general (Lange et al., 2020). Our aim was to understand how different ecologisation pathways grasp digitalisation. The originality of our approach is addressing the issue through the perception of digitalisation by French Agricultural Innovation System actors, that is, the set of diverse actors, networks, institutions and knowledge that enable innovation in the agricultural sector (Klerkx et al., 2012).

Ecologisation is promoted as a way to cope with the adverse effects of farming. These effects include loss of biodiversity, water, soil and air pollution, and climate change as well as food safety and occupational health issues. Schematically, two main ecologisation pathways coexist in agriculture, which their promotors each claim address these challenges (Dalgaard et al., 2003; HLPE/FAO, 2019; Plumecocq et al., 2018). The first corresponds to the sustainable intensification of the industrial model of agriculture. It consists in optimising inputs to increase efficiency and reduce negative externalities on the environment. The second promotes new practices that stimulate ecosystem services. It involves a more transformative and systemic reconfiguration of production systems mainly grouped under the general term 'agroecology' (Duru et al., 2015). Organic agriculture is usually recognised as belonging to the second ecologisation pathway, even if academic debate concerning their links or similarities continues (Abreu et al., 2012; Bellon and Penvern, 2014). Most research addresses the coexistence of ecologisation pathways through their ontological basis (Ollivier et al., 2018), their values (Plumecocq et al., 2018) and their actors' perceptions (Van Hulst et al., 2020). With the notable exception of institutional analyses of specific technological lock-in of certain crops or varieties, the role of agricultural innovation systems in the ecologisation of agriculture is much less widely studied (Magrini et al., 2016; Vanloqueren and Baret, 2008).

Alongside the promotion of the ecologisation of agriculture, digitalisation is also accelerating in the agricultural sector, with a bundle of new and diverse technologies (Van Es and Woodard, 2017; Wolfert et al., 2017). Digital technology consists of the codification of information through numbers which facilitates its transfer and storage. In agriculture, digitalisation covers a wide range of technologies including digital platforms or precision agriculture or connected objects or digital social networks. Here we focus on digitalisation at farm level. Through the hard-, soft- and orgware components of technology (Dobrov, 1979), digitalisation can transform not only farming tools, but also practices, knowledge processes, and work organisation. Digitalisation has led to the development of new products and services for farmers, to new knowledge and uses, but also to new players and networks in agricultural R&D (Fielke et al., 2020). On the other hand digitalisation can be framed by institutions, knowledge and actors from the digital sector as well as from the agricultural sector targeted here (Jakku et al., 2019), where it can lead to a specific digital agricultural innovation system (Fielke et al., 2019).

Although the relations between digitalisation and ecologisation are the subject of academic debate (Clapp and Ruder, 2020; Rotz et al., 2019; Wolf and Buttel, 1996), little work has directly addressed this issue. Some papers highlight the potential of digital technologies to support ecologisation of agriculture, to provide new knowledge, improve management of complexity and diversity, foster exchanges and innovations and reduce the agroecological workload (Bellon Maurel and Huyghe, 2017; Bonny, 2017). However, most social science papers are more critical of the compatibility between ecology and digital technology. Digitalisation could lead to simplification and homogenisation of production systems, loss of autonomy and of knowledge and instead promote a high-capital agriculture (Carolan, 2017; Plumecocq et al., 2018; Wolf and Buttel, 1996).

The development of digital technologies in agriculture is a process that involves a set of innovations with a strong systemic dimension (Klerkx et al., 2019). Digitalisation transforms not only exchanges of information and farmers' decisions, but also potentially the very knowledge and actors of agricultural innovation system (Fielke et al., 2019; Ingram and Maye, 2020). In other words, like other innovations, digitalisation is not neutral. It fosters system transformations and affects actors, knowledge, and power relations (Bronson, 2018). However, the systemic aspect of digitalisation and its directionality remains to be further explored.

The notion of Agricultural Innovation Systems (AIS) has been used at national scales to study the '*interactive development of technology, practices, markets and institutions*' in agriculture (Klerkx et al., 2012, p. 465), leading to a growing literature (Touzard et al., 2014). But AIS are not homogeneous. A "*plurality of socio-technical configurations, supported by different key actors pursuing different aims, and shaped by different rules, lock-in effects and path dependence, can potentially coexist in the current socioeconomic and political context*" (Dumont et al., 2020, p. 107). The diversity of agricultural models is embodied in a multiplicity of practices and is supported by a variety of institutions, organisations, and infrastructures. In other words, different paradigms built around ecologisation can coexist within AIS (Beus and Dunlap, 1990; Gaitán-Cremaschi et al., 2019). Paradigms are framed by actors and institutions, who structure power relationships (Sonnino and Marsden, 2006), thereby influencing the dynamics of agricultural systems and shaping their directionality (Pigford et al., 2018). Conversely, AIS can structure the coexistence of different forms of agriculture (Stassart and Jamar, 2009; Vanloqueren and Baret, 2009). The coexistence of paradigms may not only result in co-evolution and convergence, but also in differentiation, and divergence (Hervieu and Purseigle, 2015). As pointed out by Pigford et al. (2018), AIS tend to promote the dominant paradigm which frames technological trajectories and locks in other possible trajectories. Directionality of digitalisation is beginning to be included in the literature (Bronson, 2019; Carbonell, 2016; Klerkx and Rose, 2020). However, few studies include actors representing alternative paradigms, such as organic agriculture. Structural analysis of AIS makes it possible to account for the heterogeneity within the AIS and understand how it affects trajectory and directionality of the AIS.

The research question we address in this paper is the following: How do actors of the AIS in relation with different paradigms of ecologisation perceive and respond to digitalisation, and what are the points of convergence and divergence? We address the question by referring to the French agricultural context.

The paper is organised as follows. First, we present our analytical framework. We link the issues of digitalisation and ecologisation of agriculture through a structural analysis of sectoral system of innovation using Malerba's categories (2004). We propose an operationalisation of this framework that is consistent with the existing literature on the digitalisation of agriculture. We continue with a description of material and methods we used for our qualitative analysis. Our method is based on 38 semi-structured interviews covering the diversity of players of the French AIS. The results provide an overview of the perception and enactment of digitalisation according to the actors' paradigm. A perception of impacts and opportunities that is shared in some aspects across actors but with different aims and risk perception. We end with a discussion of our findings and their implications.

Revisiting the digitalisation process through an institutional analysis of the agricultural innovation system

2.1 Analytical framework: relations between digitalisation and the four dimensions of innovation systems

The sectoral innovation systems (SSI) concept was developed to analyse sectoral specificities in innovation (Malerba, 2004). In parallel, scholars have developed the concept of Agricultural Innovation Systems (AIS) specifically for the farming sector (see Hall, 2006; Klerkx et al., 2012). In the framework of AIS studies, innovation is considered as a '*complex web of related individuals and organisations – notably private industry and collective action organisations – all of whom contribute something to the application of new or existing information and knowledge'*. It *'includes the farmers as part of a complex network of heterogeneous actors engaged in innovation processes, along with the formal and informal institutions and policies environments that influence these processe*s' (Spielman and Birner, 2008, pp. 1, 2).

Actors' perceptions of innovation systems can be analysed from different perspectives (Klerkx et al., 2012), with the focus on processes (Nelson and Nelson, 2002), and interactions (Spielman et al., 2011), functions (Hekkert et al., 2007) or on structures (Knierim et al., 2015). We use Marlerba's analytical framework of the structures of sectoral systems of innovation (Malerba, 2002), which was already applied to digitalisation of agriculture by Busse et al. (2015). This structural analysis appears to be an appropriate way to grasp how the different paradigms connect to digitalisation within AIS. First, the framework is used to characterise change, i.e. the *transformation and evolution* of the variables of a sectoral system (Malerba, 2002, p. 258). Second, the framework is useful "*when the transformation of sectors involves not just traditionally defined sectors […], but the emergence of new clusters that span over several sectors*" (Malerba, 2002, p. 259). Third, Malerba himself acknowledged the importance of describing heterogeneity within the sectoral system of innovation (Malerba, 2002, p. 262).

The different ways of conceiving agriculture can be considered as different paradigms, i.e. different outlooks, along with the definition of relevant problems and of the specific knowledge required to solve them, supplemented by production, marketing and distribution conditions (Djellal, 1995; Dosi, 1982). The nature of the paradigm defines its boundaries, along with a framework for possible technological trajectories (Dosi, 1982) that are supported by specific institutions and organisations for knowledge exchange and innovation. Our aim is to point out how players involved in different agricultural paradigms, perceive and make sense of digitalisation, how they themselves grasp the digital concept, i.e. how they understand, are aware of, expect and transform digitalisation (Dufva and Dufva, 2018).

We analyse how actors engage with digitalisation using Malerba's categories: actors and networks, technologies, knowledge, institutions and public policies. Table 1 below provides an overview of our analytical framework, the categories and the actors we analyse and links them with the questions we aim to answer together with literature on digitalisation. Some of these studies show that the different actors of AIS (researchers, advisors, industry, farmers) have different expectations and perceptions of the risks involved in digitalisation (Fielke et al., 2019; Jakku et al., 2019). Depending on how they understand and enact digitalisation, the process of digitalisation can affect their identity and their organisation (Rijswijk et al., 2019). Moreover, the use of digital technologies can foster new learning processes and create new networks, new kinds of interactions (Eastwood et al., 2017, 2012). Digitalisation may exclude some actors, or reinforce the power of others, including upstream and downstream industries (Bronson and Knezevic, 2016; Ryan, 2019). Digitalisation can also encourage the entry of new players into a sector, in particular digital firms. Digital technologies are based on information. They influence information and knowledge processes (Higgins et al., 2017). Codification of information and knowledge makes them easy to diffuse and organise. But the codification process can change the nature of information, for instance by suppressing tacit knowledge or transforming it into explicit knowledge. In addition, organisations can benefit from knowledge creation and knowledge diffusion thanks to digital technologies. Interdependencies between humans and technologies influence workers' skills and capacities (Richardson and Bissell, 2019). Organisations can develop specific knowledge and skills to cope with digitalisation (Eastwood et al., 2019; Rijswijk et al., 2019). Digitalisation also affects both formal institutions (legislation, especially on data, public policies, etc.) and informal institutions (new ways to act, to communicate etc.), and reciprocally, institutions affect digitalisation. Institutions play an essential role in technology trajectories in agriculture (Hayami and Ruttan, 1971), and this role is underlined by many authors including Wolf and Buttel (1996), Wolfert et al. (2017), Eastwood et al. (2012), and Jakku et al. (2016).

Table 22

Analytical framework, inspired by Malerba (2002)

Category	Description	Questions	Literature informing the questions
Actors and Networks	Beliefs, assumptions, purpose	What do players expect from digitalisation? Which risks do they perceive?	Dufva and Dufva (2018) Jakku et al. (2016)
	Organisations, learning processes	How does digitalisation affect interactions within or between organisations?	Eastwood (2017) Rijswijk et al. (2019)
	Collaboration - Competition Interactions Communication - Exchange	Does digitalisation result in collaboration or in competition between organisations? Do digital players include/exclude certain AIS organisations?	Bronson and Knezevic (2016)
Technologies	Development of technologies	How do agricultural organisations engage in the development of technologies?	Jakku and Thorburn (2010) Rijswick (2019) Bronson (2019)
	Constraints and interdependencies of technologies	Are digital technologies on the market include the two paradigms? Do they account for their specificities? How are the technologies perceived? What curbs 'AgTech' development?	Carbonell (2016) Lioutas and Charatsari (2020)
Knowledge	Knowledge and skills within the organisation	How do organisations develop knowledge and skills for digital innovation?	Rijswijk et al. (2019) Eastwood et al. (2019) Jakku and Thorburn (2010)
	Learning process	Has digital innovation led to new sources of knowledge?	Ingram and Maye (2020) Eastwood et al. (2012)

Institutions and public policies	Laws Regulation Public policies Values Routines Practices	What roles do formal institutions play in digitalisation? How does digitalisation change formal institutions? How do institutions that are concerned with digitalisation articulate paradigms and digitalisation? How do informal habits, routines, practices, affect digital innovation in the paradigms and inversely?	Rijswijk et al. (2019) Wolf and Buttel (1996) Wolfert et al (2017) Eastwood et al. (2012) Jakku et al. (2016)

2.2 Organic and conventional as paradigms

To illustrate the diversity of paradigms within the French AIS, we focus on conventional and organic farming.

"Conventional farming" refers to mainstream agriculture, i.e. "*capital-intensive, large-scale, highly mechanised with monocultures of crops and extensive use of artificial fertilizers, herbicides and pesticides, with intensive animal husbandry*" (Knorr and Watkins, 1984 in Beus and Dunlap, 1990). This type of agriculture emerged in France in the post-World War II period in response to the political aim to achieve food security and has been supported by scientific, political and technical actors (Brechet and Schieb-Bienfait, 2006). In France, the development of conventional farming led to an increase in farm size (from 19 Ha in 1970 to 63 Ha in 2016), a reduction in the total number of farms (from 1 588 000 in 1970 to 436 000 in 2016), an increase in yield (e.g. for wheat from 4T/Ha to 7T/Ha) and of the use of inputs (+ 60% in volume) [102]. Conventional farming does not only involve the farm level, but the whole value chain including input suppliers, the food industry and retailers (Darnhofer et al., 2010). It has been supported by professional unions, advisory organisations, research and education. Hence, the construction of the AIS is inherent of the development of conventional agriculture (Labarthe, 2009). In France, conventional farming is mainly based on family farms, a component of the wider agro-industrial food system and has been studied as a paradigm by institutional economics (see Touzard and Labarthe, 2018 for a review). It supplies around 80% of French food (Fournier and Touzard, 2014). Criticized in France for its adverse effects on the environment and health, French conventional farming has changed over the last twenty years, notably through the integration of environmental concerns, supported by public policies (Duru et al., 2015). Some of the farmers linked to this paradigm have in fact opted for different forms of ecologisation, by optimising inputs or adopting more emblematic practices such as integrated pest management or no-till (Barbier and Goulet, 2013).

Organic farming emerged from social and ideological struggles against the development of productivist farming. The acknowledgment of organic farming within AIS, which was also framed by and for conventional agriculture (Brechet and Schieb-Bienfait, 2006), was one dimension of the confrontation between organic and conventional agriculture. The first organic group was created in 1959, followed by the creation of the French Association for Organic Agriculture in 1962. This movement led to the institutionalisation of organic farming with the creation of the Research Group on Organic Agriculture in 1978, official recognition of organic farming in 1980, followed by the creation of the organic farming technical institute (1982) and the organic label (1985) (Piriou, 2002). Thus, the development of organic farming is not only characterised by different practices and values at the level of individual farmers and consumers, but also by specific institutions and organisations which frame the balance of power in the AIS. Today, in France, organic farming is the most 'institutionalised' alternative paradigm. Its growth rate has been more than 15% for the last 15 years. Since 2018, organic farmers have been supplying more than 6% of French food and account for more than 8% of the agricultural area (Agence Bio, 2020)

Conventional and organic farming constitute two different paradigms, framed by specific actors, institutions, knowledge and organisation systems. Farmers who refer to one of the two paradigms co-exist in all the French regions, although organic agriculture has greater weight in the South of France (Gasselin et al., 2021). However, the limit between paradigms is sometimes blurred. At farm level, the ecologisation of conventional farmers can lead to practices that are very similar to those used in organic farming, and organic farmers can use external inputs similarly to conventional farmers. At the other stages of the food systems, economic organisations such as supermarkets may also choose strategies that combine organic and conventional products under general policy of food greening, which is sometimes confusing for consumers (Le Velly and Dufeu, 2016).

[102] The data come from the official census of the French Ministry of Agriculture available at: https://agreste.gouv.fr

2.3 Material and methods

Delimitation of innovation systems

The AIS framework underlines the importance of including a diversity of stakeholders who shape innovation in the farming sector (Hall et al., 2005). The AIS includes agricultural research and education organisations, advisory organisations, private sector actors in the value chain, agricultural cooperatives, public organisations, professional organisations and farmers (Klerkx et al., 2012; Spielman and Birner, 2008). We interviewed members of these different categories along with a number of digital players who characterise the dynamic frontier of this AIS (Fielke et al., 2019) (for a list of interviewees see ***Table 23***). We interviewed different categories of AIS stakeholders representing each of two paradigms (conventional and organic agriculture). The categories include farmers, value-chain players, advisory and political organisations, research and education systems, and public structures.

Digitalisation brings new actors dedicated to digital farming. Those actors may originate i) from digital firms which extend their activities to the farming sector, ii) from new organisations specialised in "AgTech" or iii) from existing organisations which create new activities (notably research and education) dedicated to digital farming. We interviewed actors who can play a key role in digitalisation directionality in agriculture, by selecting or prioritising one model, thereby strengthening or weakening organic or conventional agriculture

Another important aspect of an SSI is the technological profile of farm businesses, the demand of users of digital technologies, i.e. the farmers. We consequently conducted on-farm interviews which included the farmers' use of digital technologies, their opinion on, and their role in the AIS. For this purpose, we selected both farmers with a representative role in organic or conventional agriculture, and farmers who play an active role in promoting or expanding/demonstrating digital innovation in agriculture.

Table 23

List of interviewees (n=38); Nat: National level; Reg: Regional level (Occitanie region)

Group		Organisation	Role
Transversal (n=5)	Tr-Minis	Ministry of Agriculture (Nat)	Digital manager
	Tr-PubAdm	Public administration (Nat)	Innovation manager
	Tr-PubRes	Public research institute (Nat)	Scientific programming manager
	T-Advis	Private advisory company (Nat)	Manager
	Tr-Journ	Journalist (Nat)	Author of a book on digital farming
Conventional (n=12)	Conv-ProfUn	Professional Union (Nat)	President
	Conv-AppRes	Private applied research institute (Nat)	Manager
	Conv-coopUn	Cooperative Union (Nat)	Innovation manager
	Conv-coop1	Cooperative company 1 (Reg)	Director
	Conv-coop2	Cooperative company 2 (Reg)	Innovation manager
	Conv-comp	Private company (Reg)	Innovation manager
	Conv-advis	Advisory Services (Nat)	Innovation manager
	Conv-coop3	Cooperative company 3 (Reg)	Technical manager
	Conv-farm1	Farm 1 (Reg)	Vice president of local professional union
	Conv-farm2	Farm 2 (Reg)	Vice president of local professional union
	Conv-farm3	Farm 3 (Reg)	Elected member of professional union and technical institute
	Conv-farm4	Farm 4 (Reg)	Member of a cooperative bureau, and president of an advisory company

Organic (n=10)	Org-advis1	Advisory Service (Nat)	Manager
	Org-advis2	Advisory Service 2 (Nat)	Innovation manager
	Org-ProfUn	Professional Union (Nat)	Deputy director
	Org-advis3	Collective organisation (advisory + applied research) (Nat)	Manager
	Org-ProfOrg	Professional organisation (Nat)	Director
	Org-PubRes	Public research institute (Nat)	Scientist
	Org-farm1	Farm 1 (Reg)	President of a professional union
	Org-farm2	Farm 2 (Reg)	Member of a national professional union bureau
	Org-farm3	Farm 3 (Reg)	Member of a collective organisation bureau
	Org-farm4	Farm 4 (Reg)	Elected member of a chamber of agriculture
Digital (n=11)	Dig-StUp	Start-Up (Nat)	CEO
	Dig-Res1	Research (Nat)	Project manager
	Dig-Res2	Research 2 (Nat)	Project manager
	Dig-Educ1	Education project (Nat)	Manager
	Dig-Educ2	Agro-digital observatory (Nat)	Manager
	Dig-firm1	AgTech firm 1 (Nat)	CEO
	Dig-firm2	AgTech firm 2 (Nat)	CEO
	Dig-assoc	Firms' association (Nat)	Director
	Dig-firmTIC	TIC firm (Nat)	Manager
	Dig-farm1	Farm 1 (Reg)	Sales and training agent in an AgTech firm
	Dig-farm2	Farm 2 (Reg)	Former sales and training agent in an AgTech firm

Sampling and interviews

We purposively selected interviews representing this diversity of actors (Etikan, 2016). Most interviews were conducted at national level, but in the case of farms and cooperatives, the interviews were conducted at regional level to ensure the homogeneity of the context. We chose the French administrative region Occitanie, which is characterised by the coexistence of organic and conventional farming. The farmers we interviewed were crop farmers because this sector has been the scene of digital and ecological development for many years. All the interviews were conducted in French, recorded, transcribed, translated into English by the authors and checked by a professional.

The semi-structured interviews were divided into four parts. The first part covered general information about the organisation, its history, its functions. The second part concerned the digital activities of the organisation. The third part addressed the interviewee's knowledge about farmers' use of digital technologies. The fourth part was more forward looking as we wished to collect information concerning the potential and the risks associated with digital technologies, and the links between digital technologies and agroecology. In the interviews, we mainly asked open questions to allow the interviewers to express their opinions freely without attempting to guide their responses too much. We had a list of Malerba's categories and if certain items on the list did not come up, we then asked the appropriate questions. This approach made the interview more flexible while ensuring nothing was forgotten. The interview was more natural, and the interviewees had more opportunity to talk spontaneously. In the interviews with the farmers, we first collected data concerning their farm and the rest of the interview was focused on their use of digital technologies, farming practices, micro-AKIS and their opinion on digitalisation.

Data analysis

All 38 interviews took place between March 2019 and March 2020. The interviews lasted between 50 minutes and two hours and were recorded and transcribed[103]. The transcriptions and documents provided by the interviewees were processed using MaxQDA© software. Data analysis was inspired by the methodology proposed by Ayache and Dumez (2011) and Miles and Huberman (1994). First, we read the transcriptions with no attempt at categorisation (Dumez, 2013). Next, we coded the transcriptions based on Malerba's broad categories as outlined above: actors and interactions, technologies, knowledge, and institutions. In each category, we created inductive sub-topics grouped in the eight sub-categories listed in Table 3. The first author coded all the interviews. Results of coding were discussed with the two co-authors, which led to a second coding process. Consistency was achieved by saturation. We condensed data using summary sheets of interviews and a matrix that cross-referenced themes of analysis and interviewees (Miles and Huberman, 1994). After listing the different results per actor and category in the first level of analysis, we added an inductive level of analysis to highlight the main transformations, gaps, and stakes involved.

Results

Our results show how the different categories of actors, i.e., those belonging to digital organisations and those who represent conventional and organic paradigms, perceive and enact digitalisation. ***Table 24*** summarizes the actors' statements concerning the different categories used for the data analysis. The following sections present the results according to the five major stakes that emerged: the diversity of expectations, the key role of knowledge and technologies, the new interactions between actors generated by this cross-sectoral transformation, the specific role of digital actors in the AIS, and the crucial issue of perceived risks.

[103] For technical reasons, interviews with two farmers were not been recorded and could thus not be transcribed

Table 24

Summary of actors' key perceptions and enactment of digitalisation

	Knowledge		**Technologies**		**Actors**		**Institutions**	
	Capabilities	Creation/Exchange	Development	Constraints	Global vision	Interactions	Formal	Informal
Organic	Developing farmers' skill is essential Lack of projects about digital and organic farming	Digital technologies enable sharing of experience, capitalisation of knowledge, ecological processes and the analysis of practices. Complementary to real exchanges	Internal development of technologies to capitalise on and exchange information/knowledge	Many of the technologies not suitable for technical, organisational, or economic issues	Possibility to manage complexity and the global technical, economic, social system Risk of dependence, of loss of know-how and power	Few partnerships with digital players due to differences in global vision of digitalisation; some informal exchanges	Environmental norms are associated with digitalisation There is no public support for digital technologies aimed at collaboration	Some actors' conception of farming may be against digitalisation because they can be based on costs/investment reduction, autonomy…
Conventional	Important development of digital skills within human resources of organisations to enact digitalisation	Need to develop data management to create value for their organisations – Added value is expected from the use of traceability data	Adoption of new technologies, co-development and development. Economic strategy: sell services, meet the demand for precise traceability	Problem of data ownership – of misuse by farmers – For farmers: need to better account for field realities	Digitalisation: a way to renew the economic model of farming organisations, change the negative image of farming, increase efficiency. Risks concern data ownership	Collaboration with digital organisations to test, to promote or co-develop digital tools. Could lead to market foreclosure	Legislation drives digitalisation - Need to adapt formal institutions to protect farmers' ownership of data and to ensure interoperability	Farmers' routines and culture are seen as a major obstacle to digitalisation

Specialised in Digital	Farmers' lack of skills curb the use of digital technologies. Digital organisations have the necessary skills to process data	Data and digital technologies could help experiment, model and predict, undertake global analysis…	Technologies are needed to help farmers digitalise their farms. Technologies are adapted to all kinds of farming including organic farming	Issues of data access, data quality, compatibility, complexity, economic models	Digitalisation is still in its infancy. Digitalisation is necessary for economic and environmental stakes. Data is an immaterial capital	Need for agricultural organisations to reach farmers. Digitalisation requires data sharing. Issues of governance	Legislation and regulation is at the basis of digitalisation but can curb some digitalisation	Farmers routines are a major obstacle to digitalisation
Transversal	Early investment in digital through regulation – Need for digital training for farmers	Data generated by digital tools could create knowledge but there is need for cooperation, sharing and means	No development of technologies	Potential of digital tools for environmental sustainability? Issues of adaptation to a diversity of farming systems	Digitalisation is seen as a potential for policy implementation – Digitalisation has potential but can have unintended negative effects	Digitalisation generates more interactions between agricultural players. Need to keep a watch on digital evolution	Legislation is a major development factor but innovation is not in their hands but in the hands of economic actors	Agricultural sector needs to change its habits to enable radical innovation

3.1. A diversity of expectations partly linked to organic vs conventional paradigms

The actors mentioned different expectations concerning digitalisation (cf. the *global vision* column in Table 3). Some impacts of digitalisation were expected by all. This includes optimising practices, accessing information and advice, gaining traceability, managing hazards and risks, or improving technical and economic management of the farms. Farmers also mentioned convenience and time saving. However, divergences can also be noted referring to communication with consumers, knowledge and value creation. Digitalisation is considered by conventional actors more as a way to create new economic opportunities while organic actors consider it more as a way to develop knowledge.

A set of opportunities identified by the interviewees concerned communication with consumers. Conventional actors mainly mentioned traceability as a way to improve communication and the marketing of agricultural products. One interviewee cited a statement heard at a meeting with a mass distribution actor: *"We're selling a product, it's true, but what we're missing is the story of the product."* Using digital technologies, organisations can ensure increasingly precise traceability and hope to gain added value. Organic farmers see digital technologies more as a way to improve sales, to deepen interactions with consumers, or create direct marketing chains.

The development of environmental regulations and private standards (such as implementation of the HVE[104] certification in wine, or CRC[105] in cereals) promote digitalisation tools that are consistent with traceability.

"The regulatory obligation to register practices, manage organic fertilisation, register for the Common Agricultural Policy etc., are what actually drove farmers to digitalisation. » (Conv-advis)

Another set of opportunities concerned the emergence of a new market based on data and digital technology. Some conventional agricultural organisations consider engaging in digitalisation and being able to propose digital services to their farmers as an economic strategy. They invest in digital technologies to ensure they will still be present on the advisory market tomorrow and to find '*new economic models*' in the current legislative context (especially the obligation to separate sales and consultancy). For some of these organisations, the objective is clear: it is to sell services. Moreover, digital technologies are considered to be essential to cope with farming issues: environmental impacts, animal welfare, profitability, working conditions, attractiveness. Digital technology is seen as 'the future of agriculture' and as a precondition for their future survival. And also as a way to improve the image of the agricultural world in the eyes of society because it vehicles an image of a modern sector that embraces environmental issues.

"*So, we've got a market [plant protection products] that's probably going to decline. And so we have to position ourselves with respect to other niches that can be vectors of profit.*" *(Conv-comp)*

"It will help farmers show society [...] that they are doing better and better and that they are willing to profit from all the new technologies to improve their production." *(Conv-ProfUn)*

In the same line of thought concerning digitalisation, agri-digital players underline the potential advantages of digital technology: gains in productivity, yield, time saving, security, forecasting, better management and communication, simplification, and efficiency. Data are seen as a value, as *"intangible capital" (Dig-firm2).* For these actors, digitalisation is seen as essential for the future of farming to cope with agricultural stakes including environmental problems, climate change and new societal expectations. They mention a necessary and inevitable transformation that will revolutionise farming. The use of digital tools in farming practices is seen as intrinsically

[104] HVE stands for 'High Environmental Value'. It is a public French certification launched in 2011 to label the global management of an environmentally friendly farm.("HVE," 2020)

[105] CRC stands for 'Controlled Reasoned Farming'. It is a French label which testifies to the sustainable cultivation of cereals ("*Filière CRC® - Culture Raisonnée Contrôlée*," 2020)

good and sustainable, as an objective *per se*. This development of digital technology "*is highly supported politically" (Dig-Res2)* and is strongly supported by funders and by research.

Members of organic organisations add expectations concerning learning and helping conceive the system, help in achieving systemic management of farms, creating links, exchanging knowledge, sharing experience and being able to make better observations.

3.2. Knowledge and technologies at the heart of digitalisation for conventional and organic organisations

Beyond these expectations and promises concerning digitalisation, interconnections between knowledge and technologies were underlined as major stakes by all actors. A need for knowledge is emerging with digitalisation, while digitalisation generates opportunities for the creation of new knowledge.

First, there was a consensus concerning the need for new knowledge and competencies to appropriate digitalisation. Conventional interviewees put more emphasis on knowledge at the organisational level, while organic interviewees put more emphasis on knowledge at the farm level (cf. the *capabilities* column in Table 3).

Conventional agricultural organisations emphasised the importance of developing new kinds of knowledge within their structure, such as agricultural cooperatives. Jobs and dedicated teams are being created specifically for digitalisation, and awareness raising and training are provided. Internal positions in agricultural organisations are even sometimes filled by digital specialists.

"farmers are more and more in need of experts (…). It forces us to train ourselves differently, or even to train people in certain aspects, etc." *(Conv-coop2)*

Organic organisations put more emphasis on the need to develop farmers' skills. The interviewees agreed on the need for new knowledge to increase organic farmers' autonomy to be able to appropriate the basic tools in order to manage they farm.

"*And mastering IT is essential for us[...] for people to be independent. We don't think it is complicated but [some say] it's too complicated for farmers and that it's not their job. We say it is possible to use the basic tools, and it creates critical thinking about their exploitation. » (Org-advis2)*

Developing skills at other levels, such as research and development, was also mentioned by organic actors, for instance by the French Scientific Committee of Organic Farming. However, these organisations have limited means and have other priorities.

Actors agreed on the fact that the development and use of a new technology create data opportunities that could help build new information and knowledge. The second column in Table 3 summarizes the interviewees' statements, showing that organic actors put the emphasis on knowledge creation concerning agronomic practices whereas conventional actors put the emphasis on the creation of information through traceability.

According to organic actors, digital technologies in organic farming would be useful to obtain information on regulations, trade, and machinery, to analyse and understand ecological processes, to help farmers conceive or think about their own system, to analyse their practices, while letting farmers take their own specificities and choices into account. Capitalising and sharing knowledge appears to be a key advantage of digitalisation, and these actors mentioned a '*conversion-support tool'* or a '*conception-support tools*' to help farmers engage in organic farming. They mainly considered that digitalisation could provide new "knowledge input" for designing, assessing, and sharing their farming practices. This will nevertheless still require physical and concrete approaches. The digital exchange of knowledge is seen as a way to complement real exchanges but not to replace them.

Conventional actors put more emphasis on the creation of information through traceability technologies to “better meet value chain standards and build consumer confidence and knowledge on the products”. Traceability is increasingly required by buyers (i.e. mass distributors, wholesalers, exporters) but is difficult to set up. Collective organisations hope to create knowledge as a result of data collection. However, they have difficulties in processing their data, due to a lack of resources.

Through digital technologies, digital companies hope to create new knowledge that will be a driving force for the development of their own business: digitalisation could create new forms of experimentation, new tools to perform global analyses of farming practices and environmental criteria, to improve modelling and forecasting.

“We are convinced that, as time goes by, a lot of know-how will come out of the vineyard. We are at the very beginning of the process because the speed of accumulation is not very high, so it takes time.” (Dig-firm1)

3.3. Different strategies regarding partnerships with digital actors

Cross-sectoral dynamic was perceived as a major factor for the development of the AIS. Digitalisation brings new actors and partnerships to the farming sector. Both start-ups and firms from other sectors invest in agriculture, leading to new kinds of interactions between actors (cf. the *interactions* column in Table 3).

One might think this would limit the role of agricultural organisations, but this is not the case. Agricultural organisations, i.e. cooperatives, associations, chambers of agriculture, commercial firms and advisory providers play a central role, especially in data collection but also in data "redistribution" and in the diffusion of technologies. Many digital players say that they cannot access farmers directly. They need farmers-based intermediaries to collect the large amount and diversity of data needed to run data-based tools. Agricultural organisations are also needed to legitimise digital projects.

“The objective [for our company] is not to sell directly to farmers but to sell to cooperatives or traders or management centres – which will be distributors of our solutions to farmers, because they have a self-interest in collecting and federating data to carry out their work […]” (Dig-firm2)

However, we noted differences between paradigms. Digitalisation is seen by conventional actors as an exogenous change and by organic actors as a more endogenous one.

Conventional organisations work in partnership with digital actors at different levels: to test, co-develop, or promote digital tools. These interactions may be informal or formal. When agricultural organisations collaborate with a digital firm, they position themselves as distributors, but also as service providers. They also offer support and training to farmers. In other words, they wish to transform the technology into a service they can sell to farmers. Conventional organisations see digital partnership as strategic. Digital technology is said to be increasingly providing inputs combined with advice, with machinery, with knowledge, via data links. According to one interviewee, that could lead to market foreclosure and reinforces their opinion that digitalisation is an important business strategy for them.

Organic actors are less involved in collaborative projects with new digital actors. On one hand, digital actors do not often call upon and work with the actors of organisations specific to organic farming.

« But by working with everyone in a balanced way, we mostly work especially with those who are most prominent. And you don't work much with small producers, agro-ecology". (Dig-Res1)

On the other hand, when organic organisations are called upon, it does not necessarily work out well because of the differences in the way they work and differences in values. Additionally, organic organisations have other priorities and do not have the financial means to invest more in digitalisation.

“Each time, the choice, the cultural difference is a little too strong. Even if we have a similar attitude to environmental issues, our methods are quite different.” (Org-advis3)

Although organic digitalisation is thus considered in a more endogenous way, organisations do have informal exchanges with digital players and follow the development of digital technologies.

Developers of digital technologies consider developing partnerships between organisations to be strategic. They claim that digitalisation will require organisations to set up an ecosystem to develop information systems. Sharing data and ensuring compatibility is essential to achieve efficient digitalisation. Beyond the strategic partnerships, some digital actors regret the limited space accorded to farmers in digital projects.

3.4. Digital actors do not perceive heterogeneity within AIS

Digital actors bring a new perspective to the AIS. They underlined governance issues between the different categories of actors but did not perceive differences between organic and conventional farming.

Digital actors aim to support farming through the process of digitalisation. Digitalisation is seen as an objective per se for the agricultural sector, which will have to digitalise to increase its economic and environmental performances. In the opinion of digital actors, farmers are not aware of the advantage of digitalisation and are not particularly attracted by the idea of using digital technologies. The digital organisations we interviewed either develop technologies directly (start-ups, firms), are involved in projects to develop technologies (research, TIC firm) or test technologies (educational organisations). The TIC firms want to transfer their technologies from other sectors to the agricultural sector.

“We need to evangelize, to make people understand the ins and outs of what we do” (Dig-StUp)

Digital organisations consider digital technologies suitable for both organic and conventional agriculture. They do not consider ‘organic’ as a differentiation criterion.

"In fact, at least since the beginning of the project, I don't have the impression that being organic or not influences the interest we have in it or not. I have the impression that it is transversal.” (Dig-Educ1)

Digital organisations see diverse impediments to their development in the agricultural sector. First, concerning access to data, they mention several obstacles including data quality, compatibility and technological interoperability, the cost of the technologies and the constraints caused by the specific farming context, especially long-term temporality, variability and complexity. Second, concerning data management, they underline issues of governance. Third, concerning the acceptability of their technologies, they are aware that digital technologies lead to outsourcing part of the analysis, which may discourage farmers from adopting the technologies. Fourth, they emphasize the capacity of the farmers to pay and to use digital technology.

“To do big data and analysis, you need good quality data. And that's hard to get” (Dig-assoc)

“And in all projects, whatever the technology, the weak link is governance.” (Dig-Assoc)

“When we use an interface like ours there is this idea that behind it they [farmers] outsource part of the data analysis and they have to accept that. And I think that's very difficult to accept.” (Dig-firm1)

3.5. The crucial issue of perceived risks by actors from the two paradigms

The actors emphasized the risks associated with the opportunities they mentioned. Organic actors underlined risks related to knowledge while conventional actors underlined the value of the data.

Both organic organisations and farmers listed many risks: in particular, that these technologies are too expensive, the risk of becoming dependent on them and of losing power, the "risk of standardization", the risk of data-hacking or data appropriation. Other risks mentioned included stress or the time required, loss of concrete interactions between people, loss of connection to the land and loss of local knowledge. Specific problems were mentioned when farmers do not have the necessary digital tools or the necessary skills to use them. Digitalisation sometimes -and in some ways- does not match the philosophy of some organic farmers or is simply too disconnected from their way of life. In particular, organic farming may reduce costs and investments whereas digital technologies may require investments.

Consistently, not all the digital technologies currently under development are considered to be suitable for organic farming, either for technical or socio-economic reasons: they may not suit the economic model, the farmers' ways of thinking and decision making, etc. As one farmer pointed out, he cannot use his farming software properly because it is not designed for a global reflection about the farm: it is designed for a technical itinerary, or plot management rather than for general management at scale of the whole farm. The farmer's reservations are reflected in a comment made by an advisor:

"But for us, in the way we advise, we consider that in organic farming, decisions must really take the whole farm into account (…). You either have to visit the farm or at least talk on the phone, and give really customized advice. » (Org-advis1)

Digital technologies are complex and complete control over them does not seem possible to those actors. This could change the balance of power between actors.

"Beyond loss of know-how, the balance of power in an agricultural system will be upset. In other words, we're going to be very dependent on the equipment or services provided in connection with these devices, on data processing, which is sometimes a little bit of a black box too." (Org-advis3)

To ensure the technologies meet the organic organisations' own requirements, they may develop them in-house, often through a bottom-up innovation process: an innovation is designed, implemented and tested on a local scale and then, if it works, it is upscaled. Most of the technologies developed by organic organisations concern knowledge management and exchange.

"So we obtained the tool at the national level, we invested some money in using and improving it based on the feedback we had already received, and that was good because we had a very good basis." (Org-ProfUn)

Conventional actors underlined the risks associated with data ownership, especially the risk that AgTech actors grab all the value created. They also mentioned the risk of farmers being excluded, because of the lack of infrastructure, skills or because of the cost. Farmers mentioned additional risks concerning the reliability of digital technologies and dependence on repairing it, and stressed the risk associated with the extra cost of the equipment when farmers already face economic problems.

Uncertainty concerning the value of the data, farmers' capacity to understand the potential of the technologies, and misuse of tools by farmers are cited as constraints by organisations involved in the development of digital technology. For their part, farmers testified to the need to better account for on-field realities in the design of digital technologies.

It is thus clear that diverse visions of digitalisation co-exist. Depending on the vision of digitalisation they vehicle, institutions that frame digitalisation could thus promote the directionality of this trajectory.

Discussion

In this paper, we address the question of how actors of AIS perceive and respond to digitalisation depending on their relation with the two different ecologisation paradigms. We highlight convergences and divergences.

4.1. Digitalisation beyond paradigms

Our research confirms that digitalisation not only changes technological possibilities but is involved in the reorganisation of the whole AIS in interrelationship with multiple factors, as suggested by previous studies (Busse et al., 2015; Fielke et al., 2019; Rijswijk et al., 2019). Interactions among actors, knowledge and institutions are jointly modified by digitalisation within the AIS, revealing characteristics that are shared across different ecologisation paradigms.

i) Whatever their paradigm, agricultural organisations play an important role in digitalisation, by acting as an intermediary between digital firms and farmers, but also by being proactive actors of digital development and in gathering, analysing and transferring information. Digitalisation does not reduce the role of intermediaries, but may even reinforce it, as shown by Busse et al. (2015). This is a further illustration of the role of innovation brokers in agriculture (Klerkx and Leeuwis, 2009).

ii) All the actors we interviewed agreed on the potential of digitalisation to improve working conditions, to optimise practices and to manage risks. They also mentioned possible advantages for economic management of farms, traceability, information for consumers, information and training for farmers. Digitalisation of agriculture is thus a part of the regime of "technoscientific promises" (Joly, 2010).

iii) On the other hand, all the interviewees mentioned different risks that could limit the adoption of digital technology or lead to the exclusion of farmers. Economic risks for farmers are described as being linked to the cost of the technologies, lack of skills or dependence on outsiders to repair the machinery. With the exception of 'digital farmers', farmers agreed on other risks concerning data hacking or data appropriation by value-chain actors. They also referred to the risk of the technologies not being appropriate for small farms. These results are consistent with the perception of digitalisation in the New Zealand AKIS, and of Big Data in the grain industry in Australia (Jakku et al., 2016; Rijswijk et al., 2019).

iv) The need to take control of the ongoing digitalisation was mentioned in both paradigms. Actors of the AIS want to be pro-active agents of digitalisation rather than passive receiver. They aim to reach the final stage of digi-grasping described by Fielke et al. (2021). All those interviewed emphasised that digital technology should complement other kinds of innovation, not only technological innovation. This is recognized by Rotz (2019) as a major challenge to digitalisation.

v) Digitalisation affects knowledge in a back-and-forth movement: it creates a need for new knowledge for digital technology, while simultaneously creating new knowledge. The creation and diffusion of knowledge is a major evolution, as shown by the literature review by Fielke et al. (2020). But making this knowledge effective turns out to be complicated, because of the diversity of needs and the context, and the management of complexity, among others. Several organisations claim they have data but cannot perform the analysis because they do not have the necessary means. Various transversal actors even think the value of the data is a myth: they believe agricultural actors hope to exploit the value of data, which will not happen.

vi) Regulations, standards, and specifications were considered by the interviewees as major drivers of the accelerated development of digital technologies. Digital technology may be both the cause and the consequence of changing regulations, allowing new kinds of regulations to be established and enabling new forms of control and traceability (Pearson et al., 2019).

On all those points, digitalisation appears to be more a source of convergence than of divergence between actors with respect to the conventional versus the organic paradigm. This convergence results from the perception of shared advantages (better information, work made easier, etc.) or problems (autonomy, learning and evaluating the technologies, etc.). Our results provide a basis for reflection or action on digitalisation that incorporates the diversity of farming systems.

Convergence may also be linked to the changing dichotomy between paradigms, as this distinction has become less clear (Sonnino and Marsden, 2006). The rapid development of organic farming is leading to hybridisation mechanisms between organic and conventional organisations. On the one hand 'conventional' organisations, especially cooperatives, are extending their activities to organic farming (Stassart and Jamar, 2009). On the other hand, organic farming organisations are incorporating innovations that allow them to scale up and "become conventional" (Le Velly and Dufeu, 2016). The distinction between the two paradigms and their institutions is still applicable. However, in practice, there is more and more a form of continuum. Thus, some "conventionalised" organic actors may have a "conventional" vision of digitalisation.

4.2. A diversity of desired trajectories of digitalisation

Although this digital transformation is global, it is not perceived in the same way by all the actors and points of divergence exist between organic and conventional players concerning their 'digi-grasping' (Dufva and Dufva, 2018; Fielke et al., 2021). Digitalisation could reinforce different directionalities of the AIS.

i) The main differences between organic and conventional players appears to be in the directionality each expects of digitalisation.

Digitalisation for traceability is expected by conventional actors whereas organic actors mention the risk of standardisation, fearing that the "industrialisation" of organic products may result from norms linked to or imposed by digital technologies aimed at promoting traceability (Klerkx et al., 2019; Ringsberg, 2014; Rotz et al., 2019).

Digitalisation for endogenous knowledge is expected by organic actors, who hope digital technologies will help them conceive and analyse their production systems in a systemic way and will support experimentation. However, this is not how digital technologies are currently designed, they are more segmented than holistic, more top down than bottom up. This could lead to discrepancies between digital technologies and organic farming. Organic actors mention the potential risks of loss of power and know-how.

Digitalisation for value creation is expected by both conventional and digital actors, who hope to improve the image of agriculture and its attractiveness, to improve profitability,

and limit environmental impacts. Conventional farmers and their organisations mention risks concerning the ownership of data.

ii) Here we refer to different innovation processes and strategies of digitalisation. Organic players underline the importance of farmers' training and of the design specific technologies to support their own vision of digitalisation. Conventional players collaborate with digital players with the aim of rendering farmers' activities simpler and more efficient. Thus, players involved in digitalisation differ because organic organisations focus on internal development while conventional organisations develop technical and economical partnerships.

iii) However, in our interviews, the digital actors did not perceive these different views. They work with the most influential actors and see no difference between organic and conventional farming. They consider that most digital technologies are generic and consequently appropriate for both conventional and organic farmers. However, the knowledge basis differs between organic and conventional farming, and, to be successful, farmers' knowledge must be included in digital technologies (Rose et al., 2018). Including actors in the conception of the tools is essential if the end users are to make sense of them (Bronson, 2019; Jakku and Thorburn, 2010). Not considering the diversity within the AIS, and consequently not incorporating this diversity in the conception of tools could lead to the exclusion of other forms of farming than conventional. It could reinforce the dominant paradigm. Conversely, a diversity of digitalisation could reinforce their differences.

Here, we consider organic farming as one example of the paradigm that embraces the agroecological transition in France, but not as the only one. Moreover, the diverse conception of digitalisation depends on a diversity of factors, not only on paradigms. It opens research opportunities to study digitalisation for new forms of alternative farming, or in other places, or depending on other factors.

4.3. Enriching the analysis of digitalisation of AIS by taking heterogeneity and power relations into account

Structural analysis based on Malerba's framework highlighted transformation of the AIS for and by digitalisation, while accounting for change in the nature of the AIS variables, cross-sectoral dynamics, and heterogeneity within the AIS. This analysis enabled us to highlight both convergence and divergence within the innovation system concerning the process of digitalisation in agriculture. Our conclusions are in line with the results of Fielke (2019), who showed that digitalisation leads to power issues and pointed out that powerful incumbents may capture more gains through digitalisation. There may thus be power issues between the different stakeholders (AgTech actors vs farmers for instance). We add possible power issues between different types of farming systems and different visions of digitalisation. Research by Bronson (2019; 2016) supports the fact that digital technologies are meaningful for conventional farming. Our research is complementary, as it provides insights into how digitalisation could be meaningful for organic farming according to the interviewees. It seems there is no opposition against digitalisation per se, rather against a certain definition of digitalisation that currently predominates. This conception of digitalisation tends to be prescriptive, requires high investment, concentrates power and standardises production. It is supported not only by private actors but also by some public actors (Lajoie-O'Malley et al., 2020)

This situation calls for the inclusion of the paradigm concept and of power relations in the innovation system. It invites scholars to analyse not only how digitalisation happens but also its possible directionality and how it is steered by the AIS. Transversal actors could work with digital actors to make the latter aware of this issue and to promote a diversity of research and development to avoid lock-in in digitalisation. This raises the question of the governance of digitalisation. Governance will influence which opportunities digitalisation responds to, which risks it will avoid, and consequently, which farming paradigm it will encourage. In line with the conclusion of Newton et al. (2020), it is essential to involve farmers and citizens in the decisions concerning the trajectory of digitalisation. We add the need to involve a diversity of farming systems in order to promote their diversity. In that respect, functional and relational analysis could complete this work in identifying blocking mechanisms and incentives (Bergek et al., 2008). Directionality of change also depends on the use of digitalisation by producers and the constraints they face, which, in turn, calls for further research on farmers' concrete uses and practices of digital technology.

Conclusion

Our result prompt us to take a step back when referring to the concept of digitalisation. In practice, digitalisation is not a single phenomenon with a single definition: it does not mean the same thing to different actors. Digitalisation may have different objectives, occur in different ways, and in different forms. We argue that there are no different 'stages' of digitalisation. All actors are engaged in understanding, awareness and transformation of digitalisation. But we suggest that there are different 'processes' of digitalisation. However, we question whether the coexistence of different processes of digitalisation is possible or whether power imbalances will impose a standardised digitalisation, meaning only the future imagined now by dominant actors will become reality (Carolan, 2020). Our findings thus call for the inclusion of heterogeneity in AIS to enable the development of technologies that suit different trajectories of ecologisation. We provide conceptual and empirical elements to help actors become aware of this heterogeneity. Moreover, many interviewees emphasised that digital technologies are but one component of transformation, others being changes in advisory services, in farm structure, new relations with consumers, new policies supporting open innovation. Thus, the popularity of digitalisation should not mask other dimensions of AIS and there is a need to explore further their interrelations.

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THEME 6 – LANDSCAPE INTEGRATION OF FARMING

Governance actors, networks and their mutual interactions are key drivers of the (past, present and future) trajectories of change in land-use and farming systems. This process is enacted across a wide range of spatial-temporal scales and institutional levels. Alas, the divergences in the interests and aspiration of these different actors and institutions (both public and private) make it difficult to reach consensus on directions for achieving more productive agronomical and forestry-systems that can be integrated with other land-uses and related socio-political objectives, including; biodiversity conservation, economic diversification and climate change mitigation and adaptation. To tackle these challenges, many theoretical and operational frameworks and tools have been proposed, including Ecosystem Services and an Ecosystems Approach, and Social-Ecological Systems and Resilience. Nonetheless, few aspects of these frameworks have been translated from theory into real-world management. Furthermore, existing land management systems that are intrinsically multi-functional and thus can foster sustainability (e.g. Mediterranean silvo-pastoral systems, such as Dehesas and Montados) are currently in decline. This is largely due to inadequate governance frameworks and market inefficiencies.

In such a context, Landscape Approaches can seemingly provide with an opportunity to link diverging land-use actors and objectives to converge through more innovative governance and decision-making structures, ultimately contributing to integrate agriculture and forestry alongside with other rural land-uses. This is a context where biodiversity conservation and carbon sequestration are largely menaced from a rapid and uncontrolled expansion of agriculture, and thus where landscape functional and ecological capacities can help address problems of connectivity and sustainable farming production. Alas, they have also been proposed in regions with a long history of human intervention where both cultural and natural values have long co-existed with, or even at times depended, on agriculture and forestry (e.g. the Mediterranean), and thus, where Landscape naturally provide the much-required bridge between food production and other benefits and services to be potentially obtained from the land, such as cultural ones. Last, Landscape is also considered as a spatial-temporal scale, and more concretely, as a scale to which decision-makers and land-managers operating on the ground can relate, thus being useful for land-management coordination and cooperation.

SPECIALIZATION, ABANDONMENT AND PERIURBANIZATION TRAJECTORIES ON MEDITERRANEAN LAND SYSTEMS. A PARTICIPATORY ANALYSIS FOR THE CASE STUDY OF THE COMTAT VENAISSIN (SOUTHERN-EAST FRANCE)

Scorsino.C, Flamain.F, Debolini.M

[A] INRA PACA, UMR EMMAH

Abstract: The Mediterranean is at the same time a region of stark social and ecological contrasts and a global biodiversity hotspot, where complex local evolving land use patterns compose the region's landscapes. In this context, we aimed to identify key drivers of land system dynamics and future possible scenarios to increase territory resilience in a local case study of the south-east of France (Comtat Venaissin, Vaucluse department) involving territorial stakeholders. The choice of this case study is based on global previous quantitative analysis of land system dynamics at Mediterranean basin scale, from which we operated a downscale and pursue a local analysis based on qualitative approach and stakeholders' knowledge.

Through a methodology based on both participatory approach and semi-structured interviews, we analysed stakeholders perception about ongoing dynamics and their drivers in farming and land systems, but also within the same farming systems, in terms of farming practices. In particular, we implemented a "Territory game" methodology, pushing stakeholder to work on a spatialization exercise, identifying territorial dynamics perceived as positives or negatives, and to formulate territorial issues linked with land, farm and food systems. Stakeholders' foreseen and desired futures for their lands completed this characterization of current dynamics, and will be compared to actual patterns and tendencies.

We identified two main changes in land and farming systems that involve several dynamics. The first one is a process of specialization, at territory scale but also within farming systems, which is strongly linked with vineyards expansion dynamic and has a landscape homogenizing effect. Farmers' choices, that are determined by an objective of profitability and depend, inter alia, on food sector functioning, on sanitary pressure and quality label areas, mostly explain this dynamic. The second one is agricultural decline as a result of periurbanization and land speculation, but also linked with agricultural vitality loss. Those dynamics raised various territorial issues, such as the fostering of land access or the conservation of agricultural and landscape diversity, to which we can respond by consolidating some modest dynamics perceived positively by stakeholders.

The implemented approach allows us to verify global assessed land system typology and dynamics, and to deeply understand the process behind them.

TRAJECTORIES OF CHANGE IN OLIVE GROVE EXPANSION AND INTENSIFICATION IN ALENTEJO (PORTUGAL): DISCUSSING A LANDSCAPES APPROACH TOWARDS MORE SUSTAINABLE FUTURES

José Muñoz-Rojas

ICAAM/MED-Universidade de Évora

Abstract

Olive groves in Alentejo (Portugal) have exponentially increased their extent and intensive character over the past 15 years. This has been driven by the rise in global demand for olive oil, in the availability of water for irrigation and by a strong political and social support. As a result of this, whilst in 1998 olive groves in the Alentejo occupied 144,759 hectares (15.38 % of which were irrigated), in 2015 they occupied 169,869 hectares (28.86% of which were irrigated, including 18.32 % located in the Alqueva irrigation system) (EDIA 2016 & 2017). In parallel, the traditional farm structure in olive groves is shifting towards land concentration in areas with access to irrigation, and towards property fragmentation and abandonment in marginal lands. Nonetheless, the existing governance framework is fragmented and has gaps, with policy tools focusing on individual aspects of the system, such as preventing the cutting of olive trees (Despacho Normativo 1/2002) or regulating the price of water (Despacho Normativo 3025/2017). This is all largely underpinned by technological-innovation discourses, with governance and social innovation largely missing from the discussion. A much-needed overarching governance strategy and vision for more sustainable futures of the sector remains absent. In response to such pressing challenges, this paper will discuss the hypothesis of whether a landscape approach can contribute to build novel governance frameworks that drive olive-groves towards scenarios of increased sustainability. The main goal of the paper is to discuss how these gaps in governance can be filled by designing and testing a landscape approach (Sayer et al, 2013; 2015; 2016) that can ultimately foster the co-construction of a more sustainable land-use system. To achieve this, the paper begins by identifying and characterizing the current mosaic of olive groves and land-management models and their current trends. This is then followed by an analysis of the governance actors, networks, levels and institutions driving change in the sector, including the discourses that underpin key challenges, such as sustainable intensification, and the role potentially played by a landscape approach. Scenarios of future change (business-as-usual vs others) are then discussed with a view on the next CAP cycles (2020-2032), including one underpinned by adopting a landscape approach. Research in this paper is based on a trans-disciplinary approach, ultimately aiming to contribute to knowledge co-construction.

Olive groves (and olive oil) in Alentejo (Portugal): socio-territorial and social-ecological dynamics of change

A prevailing opinion persists among the key policy, economic and social actors in Portugal on the pertinence to advance agricultural intensification if an expanding global demand and international market competitiveness are to be satisfied (Silveira et al, 2018). In parallel, growing concerns are raised about the impacts and externalities to potentially arise, calling for more sustainable forms of agricultural intensification. However, this is a term that remains largely unresolved (Garnett et al. 2013; Röckstrom et al, 2017), being frequently used to justify private strategies of growth.

In this context, the Alentejo seems to be clearly following a pattern of rapid, and largely unsustainable, agricultural intensification, despite of the constraints posed by its dry Mediterranean climate and a tradition of extensive, multi-functional agricultural systems

(Marques & Carvalho, 2017). A key factor driving intensification in the region is the long-standing public investment in the Alqueva irrigation system that has counted with legal and financial support from policy makers, and that has been facilitated by private financial investment in agriculture. The construction of the Alqueva dam was concluded in 2002, becoming the largest artificial water body in Europe. Although extensive and intensive olive groves continue to coexist in the region, the transition from traditional and extensive towards increasingly intensive farming systems has been extremely fast.

In 2016, land used for irrigated olive groves (intensive and super-intensive) was of 57% in the Alqueva area of influence (EDIA, 2017). As a result of this, whilst in 1998 olive groves in the Alentejo occupied 144,759 hectares (15.38 % of which were irrigated), in 2015 they occupied 169,869 hectares (28.86% of which were irrigated, including 18.32 % located in the Alqueva irrigation system) (EDIA 2016) (figures 1 and 2).

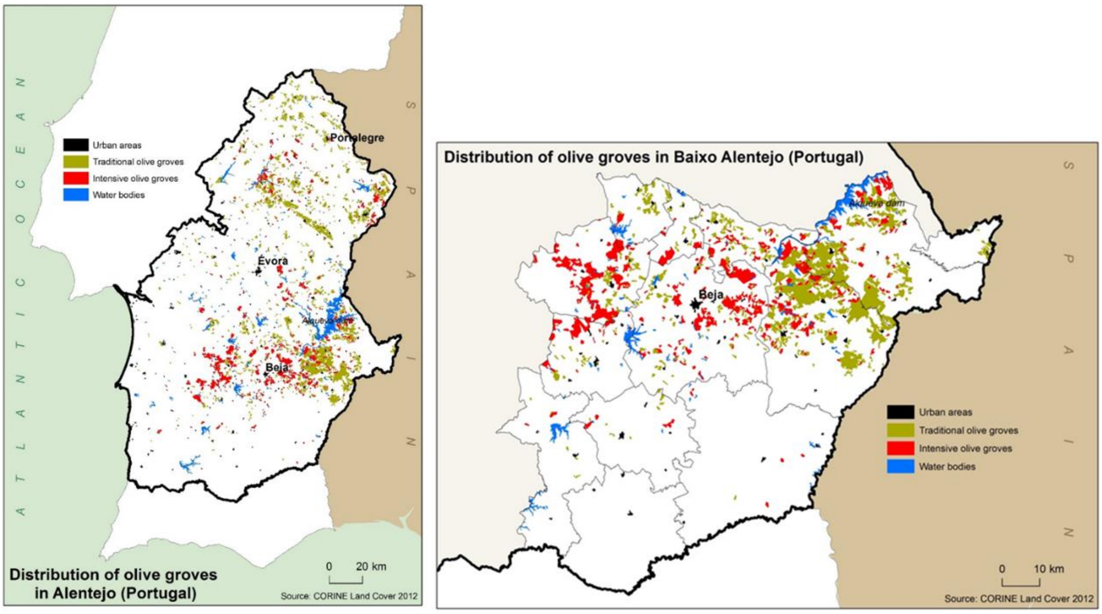

Figure 1: Distribution of olive groves in the region of Alentejo (NUTS II) and the district of Beja (NUTS III), differentiating amongst traditional/extensive and intensive/super-intensive olive groves. The location of the artificial water reservoirs in the region in their role as main material factor for the expansion and intensification of olive groves, especially the Alqueva damn, are also represented.

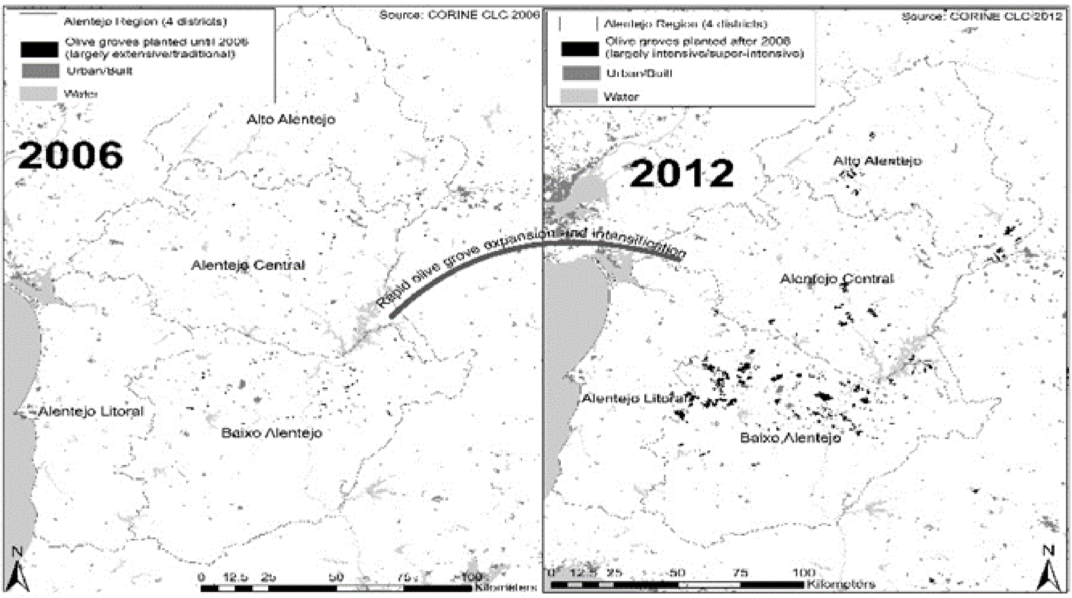

Figure 2: Map showing the rapid increase in intensive and super-intensive olive groves across central Portugal in the period between 2006 and 2012. It is relevant to indicate that the most acute period of increase in olive grove expansion and intensification started in reality immediately after the latest date represented in this figure, thus portraying a more extensive and impacting change that the one hereby shown.

In parallel, the traditional farm structure in olive groves is shifting towards land concentration (table 1) in areas with access to irrigation, and towards property fragmentation and abandonment in marginal lands, where agricultural productivity is lower.

Table 1: Change in the number of farms of olive groves and olive oil production of different sizes in the Alentejo during the period between 1999 and 2013. The parallel process of increase in the number of bigger farms and decrease in the number of smaller farms is clearly indicative of the land property concentration process which is inherently linked to the intensification trend. As with indicated for figures 1 and 2, the process of land concentration has become increasingly acute following the reflected in this table, when the irrigation perimeter of the Alqueva has become fully operational.

Size	2013	2009	1999
Total	19449	19745	22513
<0.5 Hectares	949	1101	1682
0.5<1 Hectares	4155	3598	4578
1<2 Hectares	4300	4829	5266
2<5 Hectares	4692	5101	5105
5<20 Hectares	3804	3575	4095
20<50 Hectares	896	886	942
50<100 Hectares	403	413	309
>100 Hectares	250	243	136

Governance challenges: scales, actors and networks

In the context of such rapid and acute change, the regulatory and planning framework remains fragmented, with policy tools focusing on individual aspects of the olive grove system, such as preventing the cutting of olive trees (Despacho Normativo 1/2002) or regulating the price of water (Despacho 3025/2017). This is all largely underpinned by technological-innovation discourses, with governance and social innovation largely missing from the discussion. A much-needed overarching governance strategy and vision for more sustainable futures of the sector remains absent.

In response to similar challenges in other crops and farming systems, several alternative theoretical and operational frameworks for improving governance structures and mechanisms have been proposed, although the olive sector in Portugal has so far remained quite impermeable to such proposals. The experience in the neighboring region of Andalucía (Infante-Amate, 2014), which is the largest olive oil producing region worldwide, has so far been mainly focused on top-down planning and regulatory instruments aiming to achieve better coordination and cooperation across scales and actor-networks, having mostly failed. These failures in the policy sector has encouraged a more innovative discussion on how to progress towards more sustainable and inclusive agro-ecological alternatives (Guzmán et al, 2017), which are in direct conflict with the currently dominant agro-industrial framework.

Inspired by such agro-ecological approaches, in the Alentejo some initial hints have been lately devised looking at gaining more critical understandings of the governance gaps, limitations and opportunities of the system, following rationales such as the one that is shown in figure 3. Findings indicate to a vicious circle of actor-network dynamics of de-territorialization, where the transition between an bio-economy and an eco-economy governance model (Silveira et al, 2018) that is threatening sustainability is not being properly tackled.

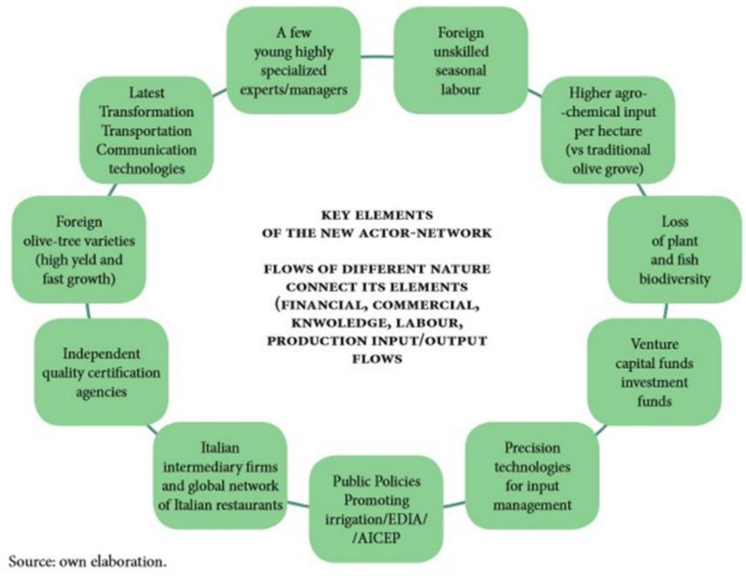

Figure 3. An abbreviated view of the actor-network associated with intensive olive grove governance in Alentejo (from Silveira et al, 2018). This figure shows the circular and vicious nature of the current bio-economy paradigm in the sector.

The Landscapes Approach

Diverse Landscape approaches have been advocated to help unravel the complexity underpinning coupled human-environmental systems and related decision-making mechanisms (Angelstam et al, 2019a). This is therefore far from a new approach, as already in 1950 Geographer Carl Troll hinted at the need for a novel landscape science that "requires continuous and close contact with the large number of disciplines in the natural and the economic and social sciences". Later, Grodzynskyi (2005) in his seminal book, reviewed the landscape concepts' natural, anthropocentric and intangible interpretations as defined in the wide range of landscape research schools that have emerged in North America, and especially in Europe. As also shown by Angelstam et al (2019a), a vast array of approaches and models aiming to embed the landscape concept into operational practices and structures related to land governance, planning and management have been suggested. These approaches are lately arising as a potential pathway to overcome the various failures encountered in the Ecosystem Services Framework, and as an attempt to tackle the sustainable governance of rural areas and related farming systems.

Actually, a certain attempt to unify and raise awareness of landscape approaches as operational tools is lately arising, with common principles being established and their applicability and advantages clearly argued. (e.g., Sayer et al. 2013; Sayer et al, 2015; Sayer et al, 2016; Reed et al, 2017). According to the Global Landscapes Forum (https://www.globallandscapesforum.org /) a Landscape Approach is about "*balancing competing land use demands in a way that is best for human well-being and the environment. It means creating solutions that consider food and livelihoods, finance, rights, restoration and progress towards climate and development goals*".

In parallel to such scientific efforts, several global level concepts and processes aiming at implementation of a landscape approach include UNESCO's Biosphere Reserves, the International Model Forest Network (www.imfn.net) and the Global Landscapes Forum (www.landscapes.org). These attempts hint to a potential for integration among different landscape approach concepts and initiatives. Advancing in such direction is urgently required to address the interconnected wicked challenges of economic development, ecological integrity, and social justice that are essential components of human well-being through a stronger territorial basis (e.g., Duckett et al. 2016).

Assessing states and trends of sustainability, which is currently advocated using ecosystem services, natural capital (Wackernagel et al. 1999), landscape services (Bastian et al. 2014) or nature's contribution to people (Pascual et al. 2017), involves challenges, which are both disciplinary and related to stakeholder engagement and participation. This is a goal that can be advanced through implementation of landscape approaches, although it requires that individuals reconnect to the landscape as their place of living which they constantly influence (Selman 2012), and building trust and trustworthiness among both academic and non-academic participants in problem-solving at a local landscape scale (Von Wehrden et al. 2019; Pinto-Correia et al. 2018). In general, ecological research dominates the ES and other common approaches (e.g., Angelstam et al. 2019b). To balance the ecological focus, social science also needs to contribute actively.

To address these issues, we proposed our own Landscape Approach that joins together the material, cultural and governance layers of complex land-use systems to ultimately seek the unravelling of landscape functions, benefits and services across a set of governance scales ranging from the region to the farm plot (figure 4).

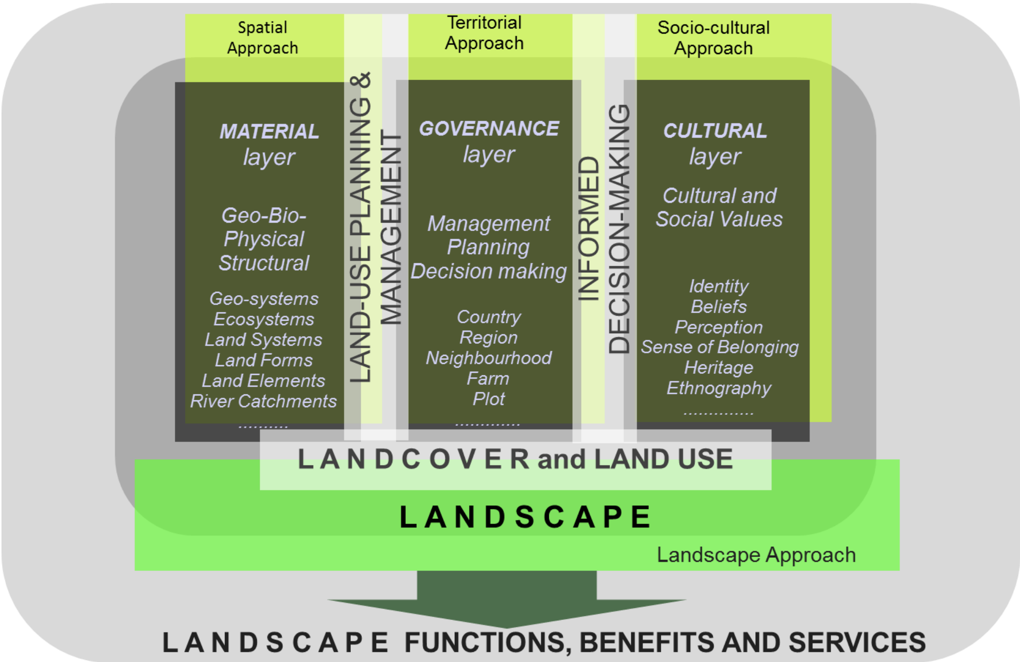

Figure 4: Theoretical framework for a landscapes approach that uses a joint spatial (material), territorial (governance) and socio-cultural analytical framework to unravel landscape functions, services and benefits using land cover and land-use as entry point where the ecological and social meet.

Transition pathways currently on-going in olive groves in Alentejo are especially well placed as object of study for the application of a complex analytical approaches such as the one described in figure 4 can be useful. The scale (moving towards increased homogeneity and simplification of the landscape, beyond the farm and farm-plot), social-ecological complexities (with implications over local economies), cultural (impacts on landscape character and significance), governance (outsourcing of decision centers away from the region and even the country and towards the global market nodes) and ecological (negative impacts of landscape mosaic changes) aspects of the intensification and expansion of olive groves makes this analytical framework ideal to better understand the consequences for sustainability and resilience of this rapidly shifting farming system.

Figure 5. Portrays of the new olive grove landscapes arising in Alentejo through the processes of intensification and expansion of olive groves leading to a simplification and loss of character with profound effects on society, economic and environmental aspects, thus demanding landscape-based solutions.

Future scenarios of change

Our research in this paper is based on a trans-disciplinary approach, and thus ultimately aimed to contribute to knowledge co-construction. This is indeed a central component of any landscape approach, both in theoretical (Sayer et al, 2013) and operational (Sayer et al, 2015 & 2016) terms.

Since a cross-scale and sustainability-oriented understanding of complex social-ecological systems is a key aspect of any landscape approach (Sayer et al, 2013, 2015 & 2016; Angelstam et al, 2019), it became crucial to generate scenarios, and to identify underpinning narratives (figure 6), of future likely change and impact on the wider olive grove farming system. To achieve this, the four narratives underpinning scenarios that had been developed and applied under to generically examine the financial sustainability of diverse farming systems across Europe, were used as a basis for devising how the coupled social and ecological, material and immaterial and territorial and governance aspects of the resulting landscapes would likely evolve in the mid-term future (6-20 years). This is a period of analysis under which the policy cycles (mainly 6-year CAP funding schemes), bio-physical and ecological risks related mainly to climate change and biodiversity loss and cultural shifts in perception become jointly relevant.

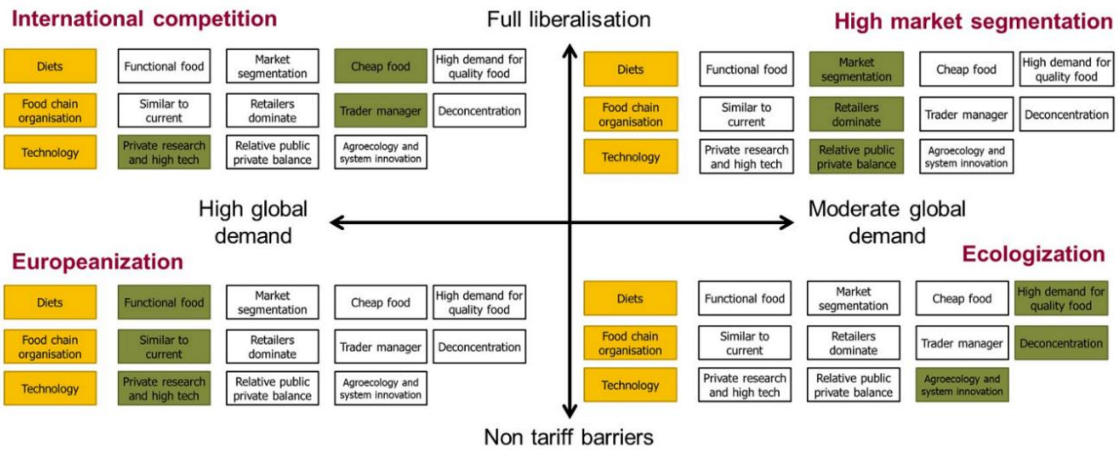

Figure 6: Mid to long-term narratives underpinning future scenarios devised for future changes in the farming systems across Europe, including in the olive groves of Alentejo. Scenarios encompass the material, perceptive, governance, scalar and ecological aspects that are all indispensable components of a Landscapes Approach.

Deliberation around these narratives took place with multiple stakeholders acting across diverse spheres and levels of governance (including farming and farming unions, public administration, the industry and research) ultimately aiming to devise more sustainable solutions for the sector (https://www.sufisa.eu/wp-content/uploads/2019/07/Deliverable-4.2.pdf). Knowledge co-construction approaches and trans-disciplinary research are in themselves key components of any Landscapes Approach (Sayer et al, 2013).

The outputs from the scenario stakeholder workshop demonstrate that strong divergences exist within a sector as complex as the olive grove and olive oil one. Divergences focus around whether olive groves should aim at maintaining current expansion and intensification trends, and especially as to what the role of public and private, local and exogenous and economic and social actors should be

Main divergences were found between stakeholders in the intensive and traditional production modes. In addition, strong divergences were detected between advocates of the governance of these complex farming systems being placed at the local level, and those others advocating externalization and outsourcing linked to global markets, operating under a clear productivist mindset. This duality could be considered as underpinning a market segmentation scenario.

Indeed, one aspect that came out of these workshops is that what sustainable development means in practice is extremely biased and seems to be very much informed by the personal economic interests of certain actors (e.g. intensive olive grove entrepreneurs and investors) holding enormous market and opinion power. This potentially complicates the much-needed transitioning between a bio-economic and an eco-economic paradigm in this sector (Silveira et al, 2018). Further complications arise from the fact that although a clear discourse of economic independence from the public sector is detected amongst many producers (thus advocating the international competition scenario), funding linked to the CAP (linked to the Europeanization scenario) is still seen as extremely relevant. This is a contradiction that does seem difficult to concile, and leads to discussions relevant to the ecologization scenario, which although being largely acknowledged as the most effective pathway towards sustainability, is seen as to idealistic and unachievable under current economic, political and social trends.

It may be argued that adopting a landscapes approach could hereby serve a double purpose beyond that already being achieved to secure dialogue and knowledge co-construction. This double purpose includes that of aligning converging worldviews and personal objectives under common goals and shared values and visions and translating this into better coordinated actions across scales.

Discussion and conclusions: applying a landscape approach to move towards increased sustainability and resilience

Landscape approaches have for a long period of time been proposed and discussed, although mainly restricted to academic circles and research (Angelstam et al, 2019a). Lately, an attempt to reach consensus around the basic principles (Sayer et al, 2013) and operational mechanisms (Sayer et at, 2015 & 2016) of what Landscape approaches should entail has been defined. Despite being originally intended for reconciling biodiversity conservation and human development targets in tropical environments (Reed et al, 2017), its potential for improving governance and stewardship towards increased sustainability and resilience is becoming apparent (Angelstam et al, 2019a & 2019b).

The recent process of rapid expansion and intensification of the olive grove sector in the Alentejo has rested on strong political and social support. This change is largely impacting the social, economic and ecological fabric of the regional rural territories in the region. In defense of these trends, over-simplified arguments linked to a bio-economic paradigm are being disseminated by those actors bearing stronger market power, detracting power from other actors advocating for alternative pathways, and thus ultimately degrading governance systems.

A Landscape Approach bringing together challenges of space and scale, knowledge co-construction, complexities in social-ecological systems and consideration of cultural preferences linked to local and regional contexts, seems to be a clear pathway to overcome current barriers towards sustainability. Nonetheless, this is indeed a very complex goal, and one for which a radical shift between the bio-economic and the eco-economic paradigm is required from both civil society, the private and the public sector. This does not yet seem to be the case for olive groves in the Alentejo. Whether a gradual implementation of the 10 principles prescribed by Sayer et al (2013) could lead to increased sustainability of the system remains to be seen.

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MAPPING PREFERRED TRAJECTORIES OF LOCAL DEVELOPMENT IN SOUTHEAST PORTUGAL

Catarina Esgalhado, Helena Guimarães

Landscape Dynamics and Social Processes Group, MED – Mediterranean Institute for Agriculture, Environment and Development, Universidade de Évora, Portugal.

Abstract

Mediterranean land systems are amongst the most susceptible to global change, in part due to the region's vulnerability to climate change and misfit within a high production demanding political and societal setting. The impact of global drivers at a local scale, i.e. the possible trajectories of change of a territory, are context-dependent, and to some extent dependent on how local actors perceive them and act upon them. In this study, we focus the territory of Serpa, Mértola and Alcoutim – three municipalities from southeast Portugal – to understand how different actors from across the territory anticipate the development of the territory and its land systems. We have conducted 22 interviews to collect individual perspectives and gathered 23 to play the territory game to find collective perspectives. From our results, we get a picture of a depopulated territory, constrained by ill-adjusted policies to its harsh conditions, including little water availability and continuous depopulation. We found contrasting preferred trajectories of development for the territory. In one hand there is a preference for prioritizing traditional land systems, usually rainfed and multifunctional. Contrasting, it is recognized a need for hydro-agricultural infrastructures that would increase water availability and allow for profitable agricultural activities and thus fixate population. The different perspectives fit with a wider debate on the role of agriculture, intensification and ecosystem services under an increasingly arid Mediterranean. The next challenge is to understand how to integrate local needs and initiatives within a broader scale strategic plan.

Introduction

Trough land management and territorial practices, human decisions and activities are a main driver of land system change (Turner et al. 2007). At a global scale, land systems dynamics can usually be linked with population, affluence and technology variables (Peña et al. 2007). Yet, these relationships tend to fade when descending to the local scale (Turner et al. 2007). How local actors and institutions interact with global trends, through their perceptions and decisions, can influence local dynamics (Nayak and Berkes 2014, Funatsu et al. 2019). Hence when aiming to understand possible pathways of development at a local scale it is important to consider how dynamics are being perceived and how actors are willing to deal with them. Understanding the relationship between global drivers and local effects can improve the capacity to push for desired pathways of development (Pinto-Correia and Kristensen 2013, Magliocca et al. 2018), by highlighting at what level of governance actions need to be taken.

In the Mediterranean basin, humans have been managing their surroundings for centuries, creating the diversity of land systems and landscapes that still today characterize the basin (Blondel 2006, Malek and Verburg 2017) Technological advances and policy support that favour market-driven agriculture, are adding pressure to the systems that have evolved and been managed as multifunction and low input systems (Pinto-Correia and Mascarenhas 1999). When viable, the tendency is to intensify production and increase productivity (Peña et al. 2007). In peripherical areas, either in geographic, economic and/or productive terms, systems are being pushed towards states of lesser human management through extensification, abandonment or afforestation (Debolini et al. 2018). Although contrasting, and varying in its degree of repercussion, all of these trends influence how land systems are being managed, potentially threatening natural and cultural values associated with certain land systems (Bugalho et al. 2011).

How local actors and institutions interact with these global forces can influence the trajectory of development (Nainggolan et al. 2012), and in turn influence global dynamics (van Vliet et al. 2015, Magliocca et al. 2018). Thus, strategies for the sustainable development of the territory are in part dependent on actors of differing positions involved in decision-making and public sector action (Angeon and Lardon 2008). although sharing biophysical characteristics, represents a very diversified region in socio-economic terms (Blondel 2006).). Studies that attempt to characterize land systems dynamics at a finer scale are important to fully grasp this region particularities and design adequate policy instruments (Muñoz-Rojas et al. 2019) and different governance scales. This paper contributes to such effort by providing a characterization of Mediterranean land systems using a case study located at southeast Portugal, including 3 municipalities, Serpa, Mértola, and Alcoutim.

The goal of this paper is two-fold 1) gain a better understanding of the local dynamics in a marginal Mediterranean area; and 2) contribute to the unveiling of desired and sustainable pathways of development for the territory. To fulfil these, we used participatory methods and involved different actors engaged in the development of land systems in the territory under study.

Case study

The case study comprises 3 municipalities in south Portugal - Serpa and Mértola in the region of Alentejo, and Alcoutim in the region of Algarve (figure 1). Guadiana River crosses the 3 municipalities, and borders with Spain from Alcoutim all the way to its mouth, in the Gulf of Cádiz. The Alqueva dam (the largest artificial lake in the Iberian Peninsula) follows the Guadiana River along 83 km of its main course and it extends to 30 km above Serpa, irrigating 23 927 ha of the municipality (EDIA 2018). Alcoutim has 4 micro damns, ranging between 24 ha and 35 ha in potential irrigated area, all below its capacity, totalling 8.5 irrigated hectares amongst all (SNIRH 2019). The Nacional park of Vale do Guadiana, (PNVG) has 69 773 ha and is part of the Natura network under the birds' directive. The vegetation is dominated by holm oak woods, with extensive cistus areas and rained plantations (ICNF 2018). The Special Protection area of Castro Verde, relevant for the protection of steparian birds in Portugal, extends through 7 695 ha in the eastern part of Mértola (ICNB/ICNF n.d.).

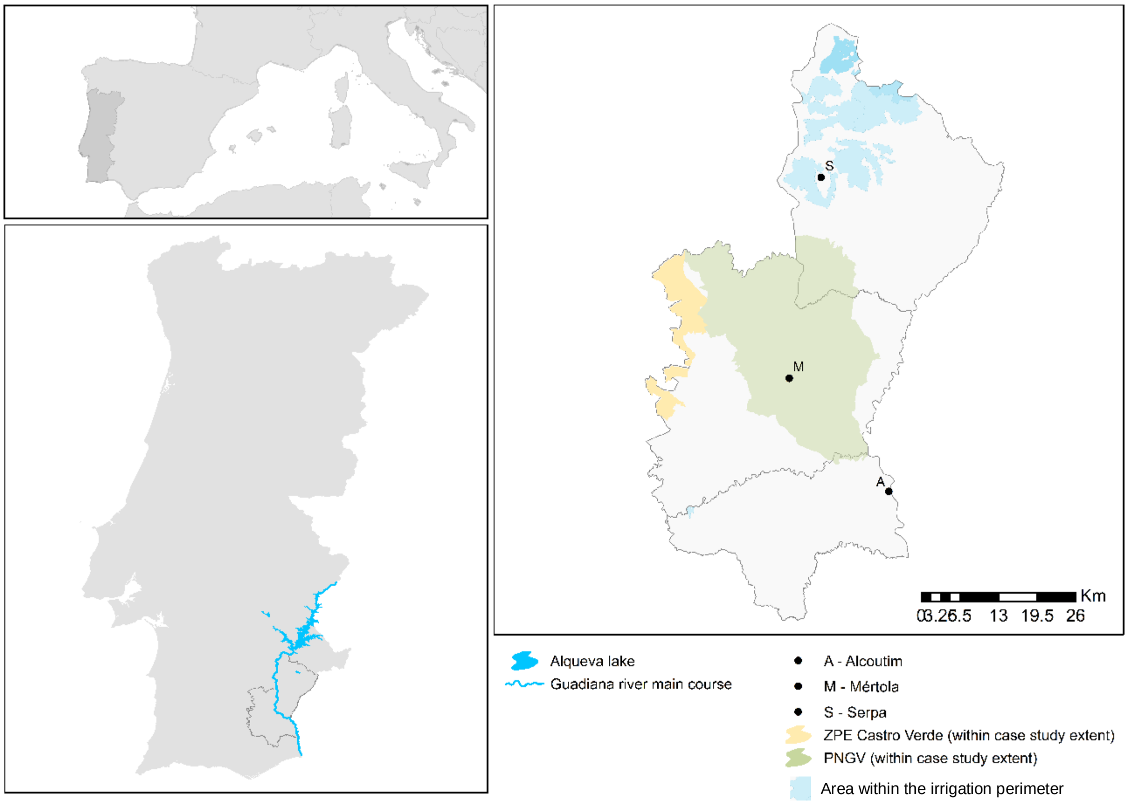

Figure 41 - Location of the case study

Southeast Portugal is highly susceptible to desertification (Rosário 2004). The climate is Mediterranean, and the region characterized by rainfall irregularity both monthly and annually (Roxo and Casimiro 1999). The territory has low ecological value and low aptitude for irrigation agriculture, except in the northern part of Serpa (Leitão et al. 2013, Magalhães et al. 2015). This together with its peripherical location, make this territory marginal in terms of agricultural production. Notwithstanding, agriculture is of relatively economic relevance, employing 15.3% of the working population in Mértola, 18,7% in Serpa and 9.8% in Alcoutim (being the 2nd, 1st and 5th economic sector employing the most people at the municipal level, respectively; INE 2011).

The landscape is a mix of agricultural, forest and agroforestry systems and scrublands. Most of the land is privately owned, with larger average property size in Mértola, and smaller in Serpa and Alcoutim. The landscape is a mix of agricultural, forest and agro-forestry systems and scrublands. Most of the land is privately owned, with larger average property size in Mértola, and smaller in Serpa and Alcoutim.

Table 25 - Summary information on the characteristics of the 3 municipalities in study

	Serpa	Mértola	Alcoutim
Area (ha)	110 563	129 287	57 536
Population density (nº/km2) [a]	14.1	5.6	5.1
UAA (ha) [b]	86 546	90 018	12 448
3-year average irrigated area (ha) [c]	8 244	649	52
Annual rainfall (mm)[a]	314.4	366.2	347.1

[a] (INE 2011)

[b] (INE 2009)

[c] For the year 2015. (SNIRH 2019)

Methods

The methodological approach developed in this case study includes a two-step process. In the first step, local perceptions on the land systems in the 3 municipalities were collected through interviews (22). In the second step we used the participatory approach called territory-game (Angeon and Lardon 2008, Lardon 2013), to promote the construction of a collaborative vision of the future of the land systems in the case study. Through a game-based approach, it is possible to provide actors with a simplified model of reality, to discuss desired outcomes and possible actions (Bishop 2011, Ornetsmüller et al. 2018), gaining a better understanding of desired and possible development pathways adapted to the territory in focus.

Territorial actors (i.e. actors with an explicit role in territorial development) were identified through a review and listing of active associations, cooperative and organizations operating within the territory, as well as relevant institutions at a local regional level. During the contact and data collection processes, other territorial actors were identified through snowballing sampling. In total more than 40 individuals were involved, from 26 different institutions including local farmer cooperatives, specific local cooperatives (beekeepers), farmer's associations, local action groups (LAG), technicians and elected representants from all 3 municipalities, technicians from regional agricultural/development institutions, individual farmers, farmers' associations, NGOs, researchers and a water management institution.

Data collection took place between October 2018 and April 2019. 22 interviews were done in person, in some cases with two respondents from the same institution in simultaneous (considered as 1 interview). The questions were divided into 4 sections: I - characterization of the land systems, II – Recent changes to the land systems; III – Visions for the Future and IV – Commercialization and local food chains. Interviewees were provided with a map of the territory to draw information if wanted and showed a map of land systems as classified for the whole Mediterranean basin, at two different time frames: 2005 and 2015 (see Fusco et al. 2018, 2019 for the land system classification methodology).

The participatory approach took place on the 17th of Abril, with 23 players divided into 5 groups with 4 to 5 players each. The approach follows a board game format to engage different territorial actors in discussing the actual state, future development and possible actions in the territory. It uses a map of the territory as a board and thematic cards to guide the discussion. The thematic cards were informed by data collected in the 1st step of this study, grey and scientific literature. The game is played in 3 steps: 1) diagnosing the present state and the main dynamics affecting the territory using the thematic cards the; 2) imagining a scenario of future development of the territory; and 3) agreeing on possible actions to meet the desired future. Each group presented its work in plenary (figure 2). A more in-depth description of the methodology can be found in (Angeon and Lardon 2008, Lardon 2013). Although the session lasted 3 hours, due to time constraints, the game was shortened with the combination of the first 2 steps. The thematic cards were used to inform a future scenario and not only a diagnosis of the present state.

The question that guided the game emerged from a preliminary analysis of the interviews and was defined as: "Which agricultural practices should be favoured to prevent desertification and strength local commercialization of agriculture products?". The players were provided thematic cards to guide the discussion that were developed with the data collected in the 1st step, defined earlier. The distributed cards were: 1)land systems, 2)soil ecological value, 3) protected areas and Natura network, 4) energy potential, 5) edaphomorphologic aptitude, 6) edaphomorphologic aptitude for tree cover, 7) local production, 8) social drivers, 9) commerce and transformation, 10) hydrographic region, 11) climate scenarios and 12) irrigation infrastructures (see figure 2 for an example of an info card). There was a skilled facilitator for the whole session and each table had an animator to guide the discussion within the groups.

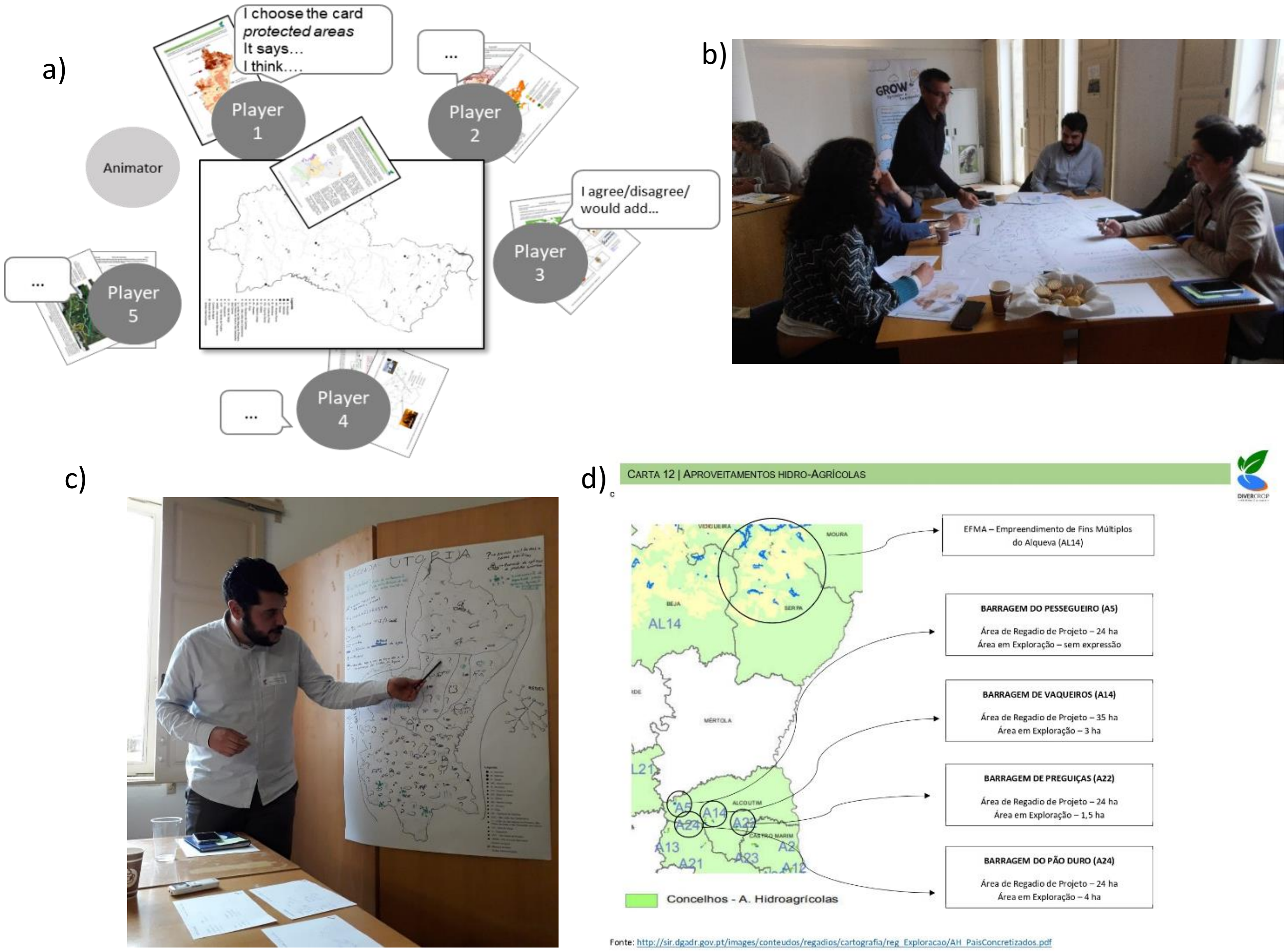

Figure 42 – a) Schematic representation of the game. The game is played over a paper map of the territory. In the each round, each player must choose amongst its cards a theme to discuss (b). At the end of the throw, the selected information must be drawn on the map. The results and maps are shared and discussed with all the groups (c). d) Example of info card (Soil Ecological Value)

The interviews and the plenary discussion of the participatory approach were recorded with the consent of the participants and transcribed. These, together with the resulting vision maps and actions from the territory game, were subject to a content analysis using an analysis grid. The results from both methodologies are presented together in the next section. Distinction between data collected by interview and participatory approach is presented if relevant. We include quotes of the actors involved to illustrate some of the discussed ideas.

Results

Establishing a reference point

Perceptions on the present state of the territory did not differ from data used to characterize the case study. For most participants, it was important to acknowledge the distinction of North of Serpa that has higher agricultural productivity and water availability. In general, the participants distinguished the territory between a) livestock production under different tree densities associated or not with fodder production; b) afforested area; and c) irrigated agriculture, offering a less differentiated characterization that the spatial analysis (Figure 3).

Past and present dynamics

The spatial analysis, developed by Fusco et al., 2018 and 2019, found little changes in the land systems between 2005 and 2015 (Figure 3). Most respondents agreed there was little change between that time frame.

Most respondents reminisced 30 to 50 years back to describe significant changes to the land system. During this period, there was a growth of the forested area, mainly Pinus, in Alcoutim and Mértola due to policy incentives. The measure “2080” (EEC regulation 2080/92, established by the decree 199/94) was mentioned often by the respondents when talking about the afforestation. In Alcoutim, respondents interpreted this phenomenon as an opportunity to generate revenue from land with low profitability. In Mértola, some argued, it was the absentee landowners who opted for afforestation. The financial support for pine plantations has come to an end, and their future is now uncertain since they are not producing fruit as it was supposed to. Interviewees attribute this lack of productivity to the installation of the pine plantations in the shallowest soils of the territory.This example was often used to illustrate how policies for agriculture and development are not suited to the reality of the territory.

“People did not want to abandon the land, because it was family property, even if unproductive. Entering the European Union and agrarian policy made possible the forestation of the properties instead of them just being abandoned.” - technician in forest association

“The dynamics in Alcoutim and Mértola revolve around what was proposed by the EU. During the wheat campaign, there was a big investment in fertilizers and a lot of soil loss. Then it came to the support for the reforestation of agricultural lands” - technician in forestry association

Irrigation is a relatively new reality in the territory, with the operationalization of the Alqueva dam in 2011 in Serpa. Some of the respondents expressed that the opportunity to use irrigation to diversify agriculture was not fully taken. Instead, market pressure, together with favourable policies, drove towards the dominance of olive yards. According to the crop cover data, Olive yards cover 75% of the irrigation perimeter in Serpa, namely intensive and super-intensive productions (EDIA 2018).

“I am in favour of Alqueva but believe there should be limits to intensification. I was in favour of the Alqueva project, and of the possibility of agricultural diversification that did not exist.” – president LAG operating the AMS

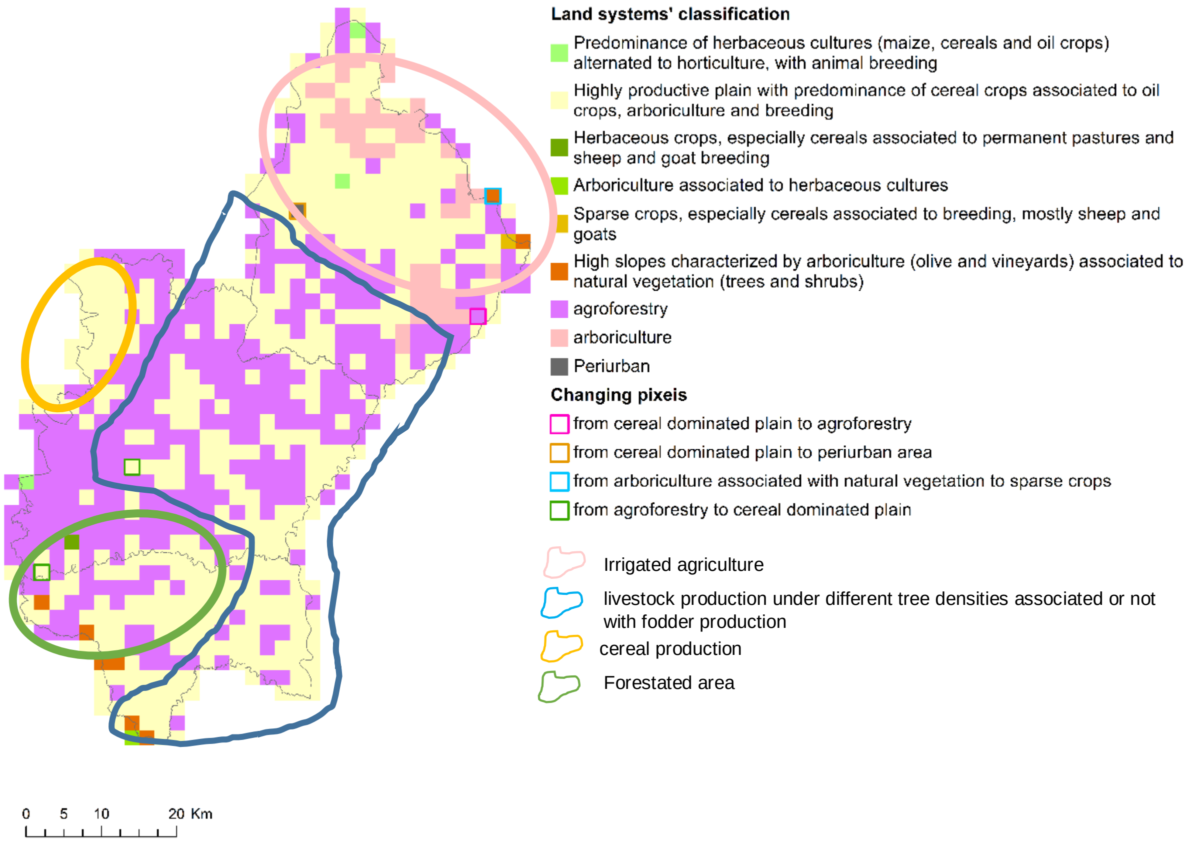

Figure 43 – Land systems as characterized in the spatial analysis (2x2 km pixels) and as described by the territorial actors (drawn shapes over the map).

Many participants presented this growth into intensive monocultural as an example of the development that they do not wish for the territory. In a contrasting position, respondents highlighted the economic development and dynamics it brought, stressing that there is room for other types of agriculture. Namely, Serpa is the host of a skill centre for biological production. Yet, it was more or less consensual that the "social model of Alqueva", as it was labelled by one of the respondents, is flawed, driven by large company interests, not promoting the right dynamics to fixate the population and revitalize the territory. Simultaneously, it was generally felt that drought has been aggravating in the last years with consequences for production.

"Rainfed will not work in the future because of water scarcity. And if it will be scarce, we need to invest in water." – farmer in Alcoutim

"Without water, there is no life. For the last years, we have been in drought (…) my neighbours that have cattle were getting seriously worried. Because food you can buy, but water no…" – beekeeper in Mértola

Although seen as stable, some respondents reported changes to livestock production in the last 10 years. Mainly, small ruminants are being replace by cattle. This due to the lower profitability and demand of small ruminants but also due to incentives from the Common Agrarian Policy (CAP). Reportedly, livestock owners in the territory have had to be granted "urgent access to water" to sustain the animals in 2018 during the drought, whereas other types of production did not enjoy the same benefits.

It also consensual amongst actors that there is not enough cooperation in the territory, and lamb producers used to illustrate the problem. The majority described them has unorganized and believing that this is hindering the sector. It is also perceived that most lamb producers do not have the means to sustain production till slaughter, thus selling their products (usually to intermediaries that sell them to fatteners) early in the production stage and still with little market value. This was considered aggravated by the isolation of the territory and its distance to slaughterhouses, increasing commercialization difficulties. Including the missed opportunity to sell the product a regional and traditional differentiation. Issues of isolation and commercialization were echoed concerning other products.

(Un)Desired Future

In a brighter prevision, montado (a valued and protected silvo-pastoral system, here considered under *Livestock production under different tree densities associated or not with fodder production)* was thought to persist*, crops* would be diversified, techniques water seeding practices would be widespread and drought-resistant species introduced. Contrasting, we also found a grimmer prediction, with continuous desertification, land abandonment, and the progressive intensification of agriculture, where it is viable, and further marginalization of areas where it is not, and degradation of traditional systems, including the *Montado.*

Despite different predictions, the desired future was transversal to participants and methodologies - a developed territory, where agriculture would play an important role, including traditional systems yet favouring crop diversity; an easiness of access to water and of distribution and commercialization of local products; and with conditions to attract and retain people (figure 4). Main consensual points concerning the future development of the territory are presented in table 2.

Differences are found on how to achieve such vision, namely the role of water in an agricultural production system:

"Agriculture must be irrigated. What is done in rainfed systems can only be valued by its services, like biodiversity." – technician at water management institution

"Rainfed production is not playing *with agriculture. […] Irrigated agriculture cannot eliminate rainfed production."* – extensive producer

Table 26 - Desired future as expressed by the actors and possible actions

Issue	Desirable future	Suggested Actions	Possible actors
Maintenance, protection and improvement of land systems	Improved soil Politics and measures fitted to extensive, multifunctional systems (of Montado in particular) Increased tree cover Predominance of multifunctional systems Exceptions in the management rules within the Natural park that would benefit important practices like beekeeping. A silvo-pastoral regime, with a minimized divide and possible clash between measures for forest and agricultural practices.	Change payment schemes and values not to favor ill-adjusted or unsustainable practices Integration of "forest" and "agricultural" policy measures considering the existence of agroforestry systems- Empowerment of farmers, landowners and policy makers on good practices, adaptive management, water and soil conservation techniques	Political decision makers Municipalities, associations, national park
Increase water availability	Water seeding – agricultural practices concerned with water conservation such as swales and ponds. Use of irrigation has a complement to rain fed systems Accessible irrigation infrastructures to a wider population	Empowerment of farmers, landowners and policy makers on good practices, adaptive management, water collection and conservation techniques	Farmers, general population, municipalities
Cooperation between actors	More dialogue amongst different entities Find and converge on common points of concern	Creation of lobby group to represent the interest of the territory near decision makers	All associations and institutions operating in the territory
Population	Maintain and increase rural population	Incentives for business opportunities and job creation in the territory	Local entities – governmental and non-governmental

ISSUE	DESIRABLE FUTURE	SUGGESTED ACTIONS	POSSIBLE ACTORS
Local market	Easiness of access to of local products in the local market and increase awareness of buyers for local consumption.	Facilitation of the placement of local products in the local market increase awareness of local buyers for local consumption	Markets, Commerce, Collective cantinas, restaurants. All with a communication strategy at a local and global scale
Transformation and commercialization strategies	Organized producers to gain commercialization strength Multi-functional processing centre in the territory. Differentiating marketing The Guadiana River as a “road” to reach a wider market	Creation of a platform of commercialization of the products from the territory	Associations and individual producers
Energetic production	Investment in small projects across the territory		

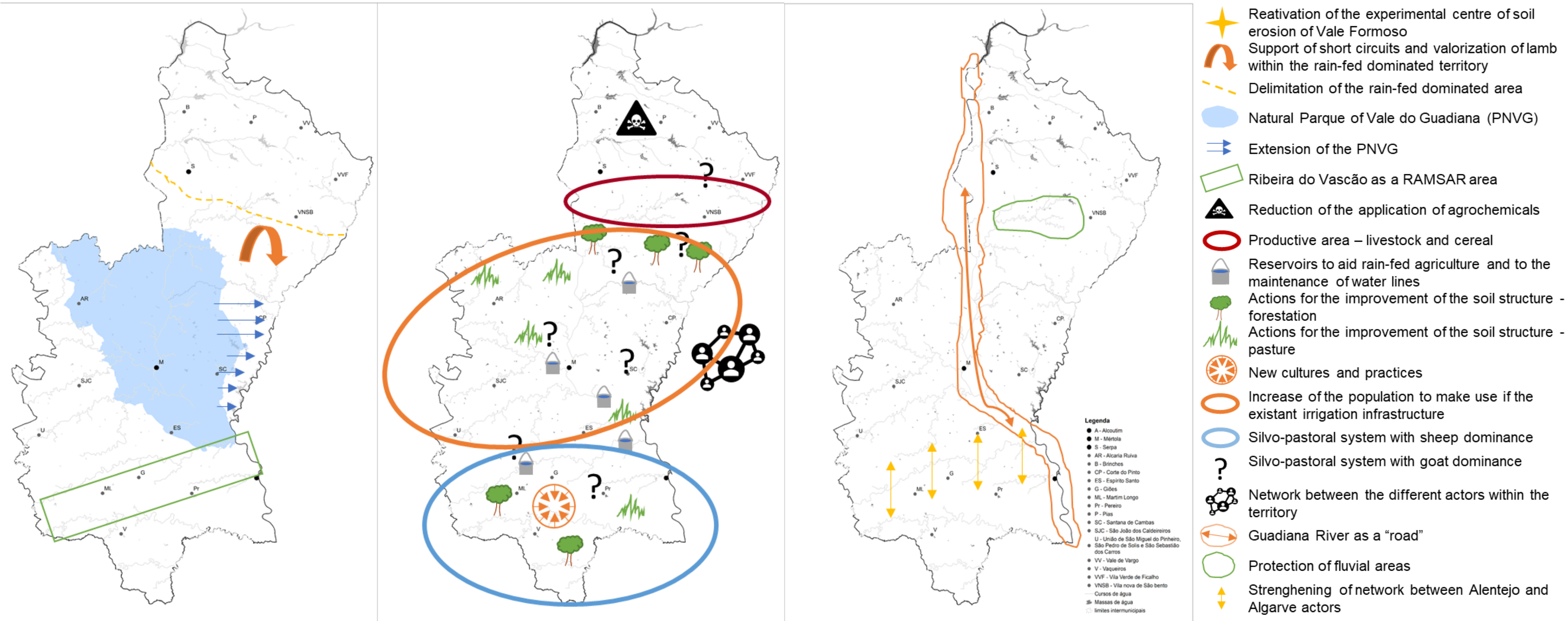

Figure 44 - Schematic representation of future scenario draw by 3 of the 5 group in play. In visions A and B there is a clear divide between the rainfed and irrigated areas (dotted line in A, and a “transition area” in B. The relevance of water resources is present in through the maintenance of the status of ribeira do Vascão, the creation of reservoirs throughout the territory and the use of Guadiana river as a “road

The idea of the introduction or increased access to irrigation infrastructure was described as both a necessity and an unwanted scenario. For some participants, irrigated agriculture was considered a mean to diversify agriculture, fight increasing aridity, and even a necessity for agriculture to continue to be viable under a changing climate. This feeling was particularly strong in Alcoutim, where most participants mentioned the construction of a dam in the municipality as a necessity. The participants that defended dams and irrigated agriculture did not frame rainfed systems as unevaluable. Instead, the persistence of the traditional systems, due to low productivity and revenue, was deemed as bound to their value beyond production, namely through agro-environmental policies. Contrasting, other participants considered the investment in irrigated agriculture would diminish the existence of extensive systems. Hence, participants refer to water seeding techniques such as swales and ponds, which can be implemented at a farm level, to increase water availability. The introduction and farming of drought-resistant species was also supported.

Many of the discussed desired developments for the future imply an action or a change, i.e. not maintaining the status quo. There is a high concordance between the actions defined by the participants and the desired future. The defined actions are summarized in table 2. Although concrete actions were agreed, in its majority actions are dependent from a higher level of decision, often relating to development or agrarian policies. However, there is also a will of organization and cooperation of actors at different levels, including producers, associations and public institutions

Discussion

Dealing with change

The main dynamics identified by the participants in this study are in alignment with trends described in the literature in marginal Mediterranean areas (Pinto Correia et al. 1998, Van Doorn and Bakker 2007, Nainggolan et al. 2012, Debolini et al. 2018). A trend towards irrigated farming, intensification of production and predominance of a single culture was one of the main issues found. In the context of biophysical constrains that characterizes the Mediterranean region, can this trend be sustained in the long term? The opinions found in this study are not consensual. Under the recent strengthening of national and international markets and increasing demand for Mediterranean products, expansion and intensification of agriculture have been encouraged in the Mediterranean (Casas et al. 2015), resulting in higher yields and crop diversification (Caraveli 2000). Yet, similarly to other areas, the fast-paced intensification within the case study region has been raising environmental concerns. Namely relating to the overexploitation and contamination of water (Palma et al. 2009, Ramos et al. 2019), homogenization of the landscapes as well as socio-economic concerns (Silveira et al. 2018). As so, when weighting on intensification in marginal Mediterranean areas it is relevant to investigate who are the beneficiaries, and how it affects the continuity of low-intensity systems, the natural and cultural values they hold, and the services they provide (Rodríguez-Ortega et al. 2017).

The afforestation phenomenon, found mainly in Alcoutim, was seen as a prime example of ill-adjusted CAP to the local context. Pine plantations add little economic value to the territory, and idle reverting depopulation. Further, afforested marginal areas tend to host lower biodiversity levels, and can increase risks of fire hazard (Marull et al. 2015, Otero et al. 2015), comparatively to well managed mosaic landscapes. Alternatively, the promotion of natural regeneration in marginal areas can potentially maintain biodiversity values (Andrés and Ojeda 2002, Navarro and Pereira 2015).

In Mértola, it is harder to distinguish a main trend of development. In one hand policy incentives led to an increase of grazing pressure (Almeida et al. 2016, Pinto-Correia and Azeda 2017). Simultaneously, erratic rain behaviour and low water providence were reported to have affected livestock effectives. Thus, although extensive life stock production dominates the landscape, there is a movement for diversification of cultures and of production methods. Projects such as the recovery of peri-urban food gardens and the implementation of water conservation practices within rainfed production systems are being supported by both the municipality and non-governmental organizations. This apparent “resistance” to global trends can be in part attributed to the civic engagement of Mértola (Morais 2010).

We found a general acknowledgement of the importance of the ecosystem services beyond production, and in particular of those provided by the traditional land systems. This reinforces the pertinence of mechanisms that allow the valorisation of these services and functions (Madureira et al. 2013, Guerra and Pinto-Correia 2016, Lima Santos et al. 2017).

A divergent shared vision

The division around the use of water for development captured in this study is evocative of the debate happening at a wider scale. A position stands by the increase of the irrigated area, not just as means of intensification, but also to safeguard production under climate change. Water requirements are expected to increase, whilst water resources to become scarcer (Costa et al. 2012). The adoption of efficient irrigation has a high-water saving potential (Fader et al. 2015), that could allow for maintaining or increasing production levels under increased aridity. Nonetheless, the deviation of water resources towards agriculture raises concerns for possible conflicts with non-agricultural uses (Iglesias et al. 2007, Döll et al. 2009, Gómez Gómez and Pérez Blanco 2012) and even more in areas arguably less fit for intensive agriculture. A contrasting position defends that rainfed systems ought to be kept and privileged. Yet, most likely adaptations will be needed concerning water management, including water conservation practices such as no-tillage (Laraus 2004, Kassam et al. 2012), that are contrary to common management strategies (Pinto-Correia et al. 2011).

Finally, the study shows that coordination and cooperation amongst actors are highly desired and considered to steer the development of the territory into the desired path. Thus, demonstrated interest by actors is not sufficient, and mechanisms should be put in place to promote higher engagement and support bottom-up initiatives.

Conclusion

Local dynamics in our case study appear to be dominated by global drivers, namely agrarian/rural development policies and market value, that privilege efficiency and production, over natural and cultural value. Local governance, in the form of associations and municipalities, alone and in partnerships, has been seeking to promote diversification of production, strengthening of local markets and to increase water availability. Despite a common vision for a developed and diversified territory with agriculture at a relevant position, disparities amongst stakeholders arise concerning the role of water and irrigation in such a semi-arid region. Although there is an expressed desire to preserve traditional and extensive production systems, it is unclear if the opportunity arises (by increased access to water), areas with lower aptitude will undergo intensification, nonetheless. These findings reinforce the idea that although local initiatives are needed and important, the development of marginal Mediterranean areas is dependent of action at a wider scale (Nacional and European), to define a common strategy towards the desired goal, attending and accommodating territorial specifications.

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LOCAL AGRICULTURE REACTION TO GLOBAL DYNAMICS. THE CASE OF VEGA BAJA DEL JARAMA, MADRID (SPAIN)

Marian Simón-Rojo [a], Andrés Couceiro[b], Julia del Valle[c], José Fariña Tojo[d]

[a] Universidad Politécnica de Madrid, Germinando

[b] Madrid Agroecológico, Surcos Urbanos, [c] Germinando

[d] Universidad Politécnica de Madrid

Introduction

Farming and land system dynamics are affected by global processes that are far beyond their power influence. Globalization, which transformed food systems and the relationships between cities is now at a crossroads (Marsden, 2013). The planet is facing an imminent socioecological crisis (de Castro et al. 2007) and food is one of the critical sectors where profound changes are needed. The group of high-level experts of the United Nations Committee on World Food Security defines sustainable food systems as ones which respect the environment, protect biodiversity and ecosystems, and satisfy nutritional needs by providing culturally acceptable, accessible and healthy food while protecting and improving rural means of life, quality and social wellbeing (HLE, 2017).

Sustainable food systems go beyond agriculture. The connection between locality and sustainability has long been claimed by food sovereignity's advocates (Holt-Gimenez, 2011). This relocation of food system is taking a different shape, though. The retail sector has incorporated "local" as part of their commercial strategies and there is an increasing presence of local food in supermarkets. The business model ain restaurants and catering are "reinvented" and adapted to consumers' growing interest in local products, sensorial experiences around food and the value assigned to the sense of belonging and identity (Cushman & Wakefield, 2018). This relocalization reduces transport, but the rest of conditions from the global system basically remain unchanged i.e large retail operators, intensive production -even eco-intensive- unbalanced relationships, etc.

The local governance context evolves as well at a high speed. Aimed to transform urban food systems at a city scale, an ally appeared recently: the Milan Urban Food Policy Pact (MUFPP) which was launched in October 2015. It has become a frame of reference, as a voluntary treaty signed by cities on committing to working in the development of sustainable, inclusive, resilient, secure and diversified food systems, to guarantee healthy food accessible for everyone. It proposes a rights based model, aiming at reducing food waste and preserving biodiversity, while mitigating and adapting to the effects of climate change. In many ways, this matches the Sustainable Development Goals outlined in the United Nations summit in September 2015. Food councils and food strategies, are relatively new tools for making local policies in the Global North, and have the potential to amplify and consolidate national and international efforts in this direction and facilitate a more synergic approach to implementing SDGs (Ilieva, 2017).

Since a decade ago efforts to re-localize the food system are gaining ground in a way that is supposed to induce changes in the primary sector, improving its conditions and sustainability. It is also well documented that the crisis and proximity to the city induces changes in periurban agricultural practices to adapt to the urban context and the growing urban demand for healthy and proximity food (Adell, 1999; Avila-Sanchez, 2011; Branduini et al, 2017). Despite this growing interest, urban food systems remain fundamentally dependent on global flows (Toth, Rendall and Reitsma, 2016) and ties with local production are barely maintained.

Land systems experience opposing trends, and while major forces keep boosting global food systems, local food is gaining prominence with different approaches. Exploring a local reality allows us to confront how the tension between these two tendencies is resolved or not. The global scale is widely analysed based on global statistics and reports. Nevertheless, understanding the context and specificities at the local level necessarily involves ad hoc field work as data are not disaggregated and qualitative information from stakeholders and local actors is not available. Therefore we select a case study in the region of Madrid (Spain capital city), to bring to the ground a critical question: Is there a local reaction to the global dynamics of the food system? Who are the social and political actors of these reactions? We explore the perception, demands and adoption of measures at the local level, distinguishing between the public and the private sector, as well as the civil society, echoing the well-known triangle of Wiskerke (2009). We can discover who gives priority to creating favorable context conditions for the revitalization of the primary sector and who links this revitalization of the sector with the relocation of the food system and which role they consider for public policies, and specifically for public procurement policies that prioritize local production.

In this paper we present the results of local participatory research developed in the Community of Madrid by Research Group GIAU+S (line of Urban Planning, Agroecology and Food Systems) Universidad Politécnica de Madrid, in collaboration with other entities.

Methodology

The research unfolds at two different scales. At a regional level, we focus on the Comunidad de Madrid, and three different projects provide insights in the evolution of the land and food systems: previous work on "Integrating Periurban Agrarian Ecosystems in Spatial planning (PAEC-Sp)" provides the background and analysis about the evolution of agrarian systems and the direct and indirect impact of urbanization. This analysis and data have been updated within the Operational Group PAUSA (Platform Organic Agriculture, Urbanism and Food Systems). From a recent project "Dynamization of agroecology in the Comunidad de Madrid" we obtain a characterization of the agroecological sector in the region of Madrid.

At a subregional scale we present the results of a case study encompassing three rural municipalities, with a strong agrarian tradition, in the vicinity of the metropolitan area of Madrid (Spain) in Cuenca Baja del Jarama and Titulcia. It has been analyzed within the DIVERCROP project. Based on interviews with relevant informants and participatory workshops, we identify the way in which local population perceive the main changes in land systems along the last ten years and the perspectives for the next thirty. The analysis goes through the evolution of the agrarian systems and practices and the orientation of food production towards local markets.

The research provides insights into the stakeholders' expectations towards the role that public procurement could play in the articulation and consolidation of an emerging sector of production that is more sustainable -in large part, agroecological. It takes into account current distributionof land dediated to organic production in the Comunidad of Madrid, and the orientation of these exploitations, with a special focus on the agroecological projects, for their innovative character. For the latter we update the data provided by the platform Madrid Agroecological which has mapped agroecological consumption and production groups and other spaces with potential to support the agroecological transition, such as public Nurseries.

Results obtained at a local scale can not be extrapolated or generalized, but working with scenarios enables us to explore possibilities. We draw on three basic scenarios concerning general data on public procurement and then move to a specific product, which was selected for the DIVERCROP project, oil, and explore the spatial implications that these scenarios would have on the region.

Regional scale. Agriculture in a region that pretends to be global: Madrid

The region of Madrid hosts 6,5 million inhabitants and aspires to consolidate as a large service hub. Since the 1980s, Madrid strives to be included in the ranks of "global cities" and plans were strategically oriented to building large transport infrastructure and promoting urban megaprojects to make the city attractive to investors, companies, tourists and citizens. Distinguished authors like Saskia Sassen (2016) position Madrid at the top rank of global cities, at least as a recipient of national and foreign investment in real state.

In terms of land dynamics, famingin the Community of Madrid is distributed almost equally between agricultural crops and livestock. Farming has become irrelevant in terms of its contribution to the GDP (0.10%) and to the workforce (0.75%). The figures on the origin of the food entering the region are eloquent: by 2003 food imports accounted for 2330.60 Mill €, by 2010 imports accounted for 98% of the total, a proportion that gives an idea of the regional dependency of the food system, both on external supply areas and on global chains.

The evolution of the land system follows a common pattern: according to Eurostat agricultural area continues to shrink, from 434,790 hectares in 2005, to 377,770 in 2013, which represents a loss of 13% of the surface. The agricultural area used and the number of farms decreased by 12%. In monetary terms, the sector remains more stable, as the reduction is limited to 5%. On the contrary, the decline is stronger in terms of employment, with a reduction of 24% of the labour force in the sector. Only the organic and agroecological farmers experience a positive trend, although the latter usually remains invisible to official statistics.

Paradoxically, the metropolitan area is a hotspot of food consumption. In the regional food industry there is a very low proportion of self-supply of local agricultural products. The regional food industry is oriented to satisfy the demands of the urban population, but not based on the transformation of local products (D. G. de Agricultura, Ganadería y Alimentación, 2017; Vilas Herranz, 2005).

The connection with the rural or peri-urban environment has almost disappeared. Farmers find it difficult to compete in terms of price with international production and, according to the research, they organize farming following subsidies' requirements. They have structural and organizational problems, without vision or entrepreneurial capacity. Monocultures are extended, and the number of farms is gradually reduced, increasing their size. It is an aging sector, in which it is not easy for new farmers to enter and who is in turn reluctant to change.

In this adverse context, and inspired by food sovereignty and agroecology, alternative practices to the global food system have emerged in the region of Madrid since 2000. Their core principles are strongly permeated by the knowledge and culture gleaned from peasant communities both in Latin America and in Spain. This is evidenced in experiences and platforms set up in Madrid, in their practical arrangements, and in their internal collaborative relationships (Simon-Rojo et al., 2018). They explicitly challenge the relationships of competition, their commitment to ecological farming practices and organic production are intended to build alternatives to the prevailing economic model. At the same time, the platforms organized around agroecology and food sovereignty act as channels of civic engagement that bring together farmers and consumers to revert the processes of food commodification that are at the core of capitalist exchange (González de Molina 1996). Their capacity to influence public policies and interact with institutions depends on the political context and the openness of local governments. It depends even more on their own ability to mobilize resources, seize their networks and the power of collective intelligence, and identify synergies between actors and proposals that enable them to be one step ahead of the institutions, pushing to overcome the latter's traditional inertia (Simon-Rojo et al. 2018).

Local scale. Struggling for an enabling environment for sustainable food systems

For the analysis at a local scale we move into the southeast area of the Comunidad de Madrid (Fig 2). It is an area with one of the most fertile plains of the region, i nwhich in previous times the cattle ranching also had an important presence. The rest of the area is occupied by rainfed crops and, to a lesser extent, by olive groves. Until the 1960s, it was an important source of food supply for the capital city. Still an intense agricultural activity is maintained, but the agrarian uses compete with mining activities and extraction sites, as well as urbanization and other artificial uses. Today, almost half the area is protected within the Sureste Regional Park.

In this context, the transformations are being boosted by a small bunch of projects, which have decided to orientate towards quality (organic production) and short supply circuits. Their performance is comparatively better than the rest of the sector, but, despite the potential proximity market that the metropolitan area implies, the model is far to be generalized.

There are general factors operating at a planetary scale such as globalization, the power of corporations and competition between territories (Maye, 2019) that all agents recognize. However, other global challenges such as planning for resilience or disaster risk reduction (and, specifically, food security) in a context of climate change and protracted crisis (Foster and Getz Escudero, 2014) are absent.

Both the private sector and the public one recognize that the proximity to a wide and diverse market such as the metropolitan region with more than 5 million people are a great opportunity. Specially if we take into account the changes in dietary habits and increasing interest in health. Social movements are the ones that do not approach the problem with the lens of “niches” (organic, quality) but do refer to the importance of reinforcing links between production and consumption, talk about identity and revisited culture around localness and food.

Between reseraches, the concept of hybridization it is becoming mainstream, applied mainly to commercialization and consumption. Most of the private sector recognises also that the food supply system combines local and global, agroecological, ecological and conventional production. Farmers are also in favor of a hybridization of the production and of diversification of channels, without finding contradictions between both options: from their logic, claiming support for local production, in connection with sustainability policies, is compatible with looking for export routes to their production, if they get better prices. Only the agroecological sector seeks to direct its production exclusively to local markets. In any case, the entire productive sector coincides with their peers in other parts of the globe, for whom the concern about economic viability precedes the rest of the issues and makes other objectives invisible (Ross, 2006). Consumer groups, social movements and social researchers give as much importance to the momentum of production as to awareness and education in consumption.

In this sense, the research provides insights into the stakeholders' expectations towards the role that public procurement could play in the articulation and consolidation of an emerging sector of production that is more sustainable -and in large part, agroecological-. Some urban policies and food strategies in nearby cities, such as Madrid, have introduced measures to promote sustainable food in public procurement[106]. A basic preliminar assessment of different public procurement scenarios, enables us to estimate the impact it would have on the sector. Given that the city of Madrid is the main pole of consumption in the region and it has already these public policies, Impact assesment is based on Madrid, that according to the official public procurement budget, in 2019 is expected to allocate 1,083,035 euros to buy food.

[106]Madrid's Food Strategy was passed in March 2017

If 20% of this public food procurement is aimed to provide a market channel to local organic farmers, it would represent 1,15% of their total business turnover. The figure rises to 4% if 70% of the public food procurement is supplied through organic agriculture.

In terms of land surface and production, agroecological farmers are a smaller group than the organic one. If 20% of the public food purchase were covered with agroecological production, that would represent 3% of their turnover a percentage that rises to 7.5% with 50% of public agroecological food purchase, and slightly above 10% when 70% of public food procurement is covered by agroecological projects. Since this second sector has smaller dimensions, the impact on it would be greater.

Resultados de escenarios:

A pesar de que estamos hablando de que la superficies necesarias para alimentar las Escuelas Infantiles con patatas ecológicas es muy reducida, en la Comunidad de Madrid no hay prácticamente superficie certificada en producción ecológica de patata, siendo esta inferior a 1 hectárea, computando tanto superficie en prácticas, como en conversión y certificada (MAPAMA, 2017). Sin embargo, sí que existe suficiente capacidad de producción en fincas agroecológicas hortícolas para cubrir la demanda de patata en comedores escolares. Los cálculos deberían extenderse para abarcar el conjunto de los productos hortícolas de temporada, como nos planteamos en la continuación de esta investigación.

la política municipal de incorporación de alimentación ecológica y de proximidad en Escuelas Infantiles. Es una política ya aprobada, aunque todavía en proceso de puesta en marcha, que responde a las demandas de la plataforma ecocomedores y otros colectivos, integrados en Madrid Agroecológico. El análisis geoespacial permite comparar el impacto potencial del cambio de modelo de suministro. Se toma como base de análisis un producto representativo y se evalúan distintos escenarios, según sea sistema de producción convencional o ecológico y según el sistema de distribución sea el normal de Mercamadrid o de proximidad (vinculado a Mercamadrid o directamente con los productores agroecológicos).

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ACTORS, SCALES, SPACES DYNAMICS LINKED TO GROUNDWATER RESOURCES USE FOR AGRICULTURE PRODUCTION: DRIVERS OF CHANGE AND FUTURE PERSPECTIVES OF THE TERRITORY IN HAOUARIA PLAIN, TUNISIA- A TERRITORY GAME APPROACH

Intissar Ferchichia, Insaf Mekkib, Mohamed Elloumic, Lamia Arfad, Sylvie Lardone

a,b INRGREF, University of Carthage, Tunis, Tunisia
c INRAT, University of Carthage, Tunis, Tunisia
d INAT, University of Carthage, Tunis, Tunisia
e INRAE & AgroParisTech, UMR Territoires, Clermont-Ferrand, France

Abstract

Groundwater resources became a recognized enabler of important rural and socio-economic development in Mediterranean countries. However, the development of this groundwater economy is currently associated with an increased pressure on the available resource and negative implications on the socio-ecological system. While there is a wide recognition that resource degradation threatens the sustenance of the agricultural system and the region's economy, viable strategies for effective water resources governance have not been forthcoming. Managing complex socio-ecological systems, such as occur in water resource management, is a multi-actor, multi-scale and dynamic decision-making process. Such a complex process involves a diversity of stakeholders. Local case studies developed in the framework of the Arimnet2 project DIVERCROP (Land system dynamics in the Mediterranean basin across scales as relevant indicator for species diversity and local food systems) have the purpose to characterize the current spatial agricultural dynamics, linked to the groundwater use, trends and impacts on agricultural practices, species diversity and local food systems. We chose to apply a territory game in the Haouaria plain, in Northern Tunisia, where farmers are currently dependent upon groundwater use for their livelihood and food security. The territory game is used as a collective learning and collaborative construction tool for building common representations of the future of the territory, perceived by local actors and planned by more global decision-makers. The perception of the territorial dynamics revealed three main issues: (i) the land fragmentation and the increasing urbanization, (ii) the agricultural products' marketing and the trade monopolies, and (iii) the pollution caused by agricultural and industrial activities. The local stakeholders emphasized the need to strengthen water resources management policies, farmland protection laws and farmers' collective organization, reforming regulated markets and providing farmers with alternative market opportunities. The local stakeholders coordinate actors, activities and spaces on their territory. Spaces such as El Garâa basin, littoral forest or transformation units are at stake to develop an integrated response to territorial issues. Local initiatives and global dynamics involve preservation of agricultural land, water management and territorial governance for an integrated development. These drivers of change have to be taking into account by the policy decision-makers.

LEARNING THROUGH SCENARIOS TO SUPPORT THE SUSTAINABILITY OF EU FARMING SYSTEMS

Daniele Vergamini[a], Paolo Prosperi[a], Fabio Bartolini[a], José Muñoz-Rojas [e], Teresa Pinto-Correia[-f] Martin Thorsøe[g], Gianluca Brunori[a]

[a] Universitá di Pisa, Italy
[e] ICAAM/MED-Universidade de Évora, Portugal
[f] ICAAM/MED-Universidade de Évora, Portugal
[g] Department of Agroecology, Aarhus University

Abstract: The increasing globalisation of food is affecting the European farming systems with growing market complexities and risks that require greater adaptive capacities, skills and smarter tools in farm and food chain management. Those tools and capabilities appear to be strongly influenced by learning processes. Learning processes are positively co-related to an improved capacity to successfully manage the farming system's conditions and changes across future scenarios. While farming systems can employ different learning patterns, the latter are mainly scenario-driven and focus on "glocal" objectives formulated by individual or networks, which are - in turn - affected by the ongoing management options and visions, as well as by limited local resources (including government extension services). If something is missing in this patchwork of skills, resources and local visions throughout participatory scenario analysis, farm managers and actors are forced to move within a temporal dimension across future alternatives and start thinking in more creative ways. The opportunity to develop more sustainable farming systems presupposes that farmers agree to include new environmental concerns in their action choices, so it implies a dynamic that entails a progressive change in their abilities and motivations to question the validity of the technical and normative knowledge acquired through past-intensive farming models. The farming system literature primarily deals with well-defined and static categories of farms, but only few papers include a temporal dimension and analyse the dynamic behind the farmers' decision-making process of learning through scenarios. Scenarios are highly temporal constructs, concerning future state of farming, with the objective to influence current decision making and action choices. There is a plentiful literature on time and temporality within sociology/geography, but this has only been sporadically integrated in the farming systems literature. In this paper we analyse how scenario analysis can further contribute to develop smart and tailored learning processes at the regional and local levels in order to tackle a key challenge for European agriculture, namely support for sustainability of production and marketing in diverse farming systems. This paper presents key results of critical reflections jointly made by researchers and stakeholders focusing on wine in Italy and olive oil in Portugal, poultry in Denmark, throughout participatory workshops aimed at the co-creation of future scenarios. Our findings provide science and policy making with insights into how farmers learn to make strategic and tactical decisions against potential future scenarios for their farming systems. The scenario analysis implemented encouraged an active learning process that influenced participants to re-examine the validity of their technical, experiential, and normative knowledge, which legitimise their reason for acting. The discussion shows which type of scenarios are favoured, actualised and how farmers collectively legitimise or avoid specific decisions in each scenario settings. Scenarios as a "future generating device" have a key role in the strategic process that guides agricultural actors to integrate specific knowledge, moral obligations, and sustainability principles to re-examine their decisions.

GREEN INFRASTRUCTURE FOR ECOLOGICAL AND STRATEGIC TERRITORIAL PLANNING TO IMPROVE THE INTEGRATION OF AGRICULTURAL LANDSCAPES

Carolina Yacamán-Ochoa [a], Rafael Mata Olmo [a], Daniel Ferrer Jiménez [a]

[a] Department of Geography, Autonomous University of Madrid, Spain

Abstract

Agrarian landscapes, biodiversity, and local food systems are facing multiple challenges in metropolitan areas. These challenges are caused by factors such as the intense urban sprawl in metropolitan regions, the neo-liberal policies on the deregulation of land use, and the ever-increasing disconnection between the areas of production and consumption caused by the globalization of agri-food production. The effects are multiple such as changes in land use, rupture of inherited socio-ecological networks, fragmented agrarian landscapes, loss of connectivity, deterioration of biodiversity, and regression of traditional agricultural activity. In this context, the European Union's 2020 Biodiversity Strategy highlighted the urgent need to extend conservation initiatives beyond protected areas and expand conservation measures to the entire territorial matrix through the creation of Green Infrastructure (GI).

Although this territorial instrument is not exempt from criticism, from our point of view, it can be innovative in the way of dealing with different problems because of its holistic approach. Essentially because it offers a variety of practical solutions based on nature for a wide range of ecological, socioeconomic, and territorial problems, which can represent a turning point in the initiatives to address sustainable planning of the open green spaces in metropolitan areas more intensely subjected to urban sprawl.

A recent critical literature review of recent literature on the subject (Yacamán, Mata, and Ferrer, 2020), of the last 10 years, highlights the gap that exists in most research papers related to the analysis of the functions and the provision of ecosystem services of the territorial matrix from a socio-ecological approach. Based on the lack of attention paid, in both academic research and policies, we propose from a more innovative socio-ecological approach, to give more weight and visibility to the territorial matrix (composed mainly of agrarian landscapes), to improve the territorial resilience from a biological, ecological, and social point of view (Berdoulay et Soubeyran, 2020). This is since the conservation of the agrarian matrix will affect the functionality of the network, reducing the urban pressure of the nodes-composed of areas that host high biodiversity- and decreasing the fragmentation of the corridors -that ensure ecological connectivity-. For this reason, it is also necessary to reverse the secondary role assigned to traditional agriculture in GI planning as in general in strategic planning (Feria and Santiago, 2015), since a is necessary for the sustainable management of landscapes that maintain agroecosystem services. In conclusion, GI must contribute to strengthening sustainable agriculture and its landscapes from a multifunctional and territorialized perspective, through specific instruments, promoting the inclusion of agricultural parks, capable of activating local agriculture, particularly peri-urban agriculture, the conservation of fertile spaces of the territorial matrix, and the agrobiodiversity of agroecosystems.

FARMERS' PERCEPTIONS OF LEVERS AND BARRIERS TO CROP-LIVESTOCK INTEGRATION BEYOND FARM LEVEL. A CASE-STUDY IN FRANCE.

Clémentine Meunier, Myriam Grillot, Salomé Carle, Julie Ryschawy

INRAE, France

Abstract: Integrating crop and livestock is broadly seen as an ideal option to maintain agricultural production levels while limiting environmental impacts on soil and biodiversity. Still, European crop-livestock farms keep declining due to globalized markets, agricultural policies and limited availability of workforce and skills. Reconnecting neighbouring specialized crop farms and livestock farms through grain, fodder, crop by-products and manure exchanges could be an alternative to overcome these limiting factors. Up to now, such collective organization is still rarely observed despite its potential advantages. In this study, we tried to understand farmers' perceptions to highlight levers and barriers to crop-livestock integration beyond farm level. We analyzed interviews of 19 farmers interested in building such collaborations in Ariege, South-western France (8 crop farmers, 7 livestock farmers and 4 crop-livestock farmers). We observed different levels of involvement considered by the farmers ranging from wishing to buy local feed or establish new crops only if a local cooperative was creating contracts, to wishing to build a strong collaboration among local group over time. Different types of collective organization were mentioned, ranging from polycentric organization involving only farmers up to a governance through a local cooperative. The main barriers were related to logistics and storage, time management, low costs of inputs as regards to the time needed to implement such local cooperation, and establishment of trust. The main levers were the existence of local cooperatives or machinery groups that could drive the project and establish contracts, new policies oriented toward collective actions and a niche-market that recognized the interest of local feed for livestock. We highlighted a strong implicit divergence between the mindsets of crop farmers relative to livestock farmers that could hinder this type of local cooperation as they have few relationships and low trust. We suggest that farmers that already have both crops and livestock may be an ideal-type to improve ties between specialized farmers. In-depth analysis of farmer motivations and long-term efforts to build strong local networks and new policies would thus be key to favour the development of crop-livestock integration beyond farm level.

COMPARING VIEWPOINTS ON AGRICULTURAL DEVELOPMENT

Hossard L[a], Ameur F[b], Ricote-Gonzalez, E[c], Leauthaud C[d,e]

[a] UMR0951 Innovation, INRA, Univ. Montpellier, France
[b] CREAD, Algeria
[c] Institut Agronomique Méditerranéen de Montpellier, France
[d] CIRAD, UMR G-EAU, Tunis, Tunisie
[e] G-EAU, AgroParisTech, Cirad, IRD, IRSTEA, MontpellierSupAgro, Univ. Montpellier, Montpellier, France

INTRODUCTION

In developing countries, agriculture remains an important sector, contributing to both a large part of GDP and to rural employment. Some countries have launched ambitious policies to develop and sustain their agricultural sector. For instance, Morocco, the case study of our research is based on, developed a program in 2008, namely the Green Morocco Plan (GMP), defining two pillars of action. The first targets large-sized farms for the development of high added-value chains, with a modern and productivity-oriented agriculture. The second tends to ensure solidarity-based mechanisms to support small and medium-sized farms, of which the large majority of Moroccan farmers are comprised, with the objective of alleviating poverty through the increase of farmers' agricultural income. The former pillar is endowed with two to three times more funding than the latter (Marzin *et al.*, 2017). Main actions for the two pillars concern farmers' organizations, economic management of water resources, technical assistance, as well as the creation and modernization of distribution channels. In accordance with the GMP, the Moroccan government also adopted a new long-term water saving program (National Irrigation Water Saving Program), aiming at developing micro-irrigation.

The Mediterranean area faces several specific challenges, in addition to population increase and land fragmentation, these latter being common to most developing countries. Indeed, the Mediterranean region is foreseen to be a hotspot for the impacts of climate change, thus presenting a high vulnerability to global changes (Giorgi and Lionello, 2008). Vulnerability to climate variability and changes may be even more prominent for irrigated systems, which are common in the southern part of the Mediterranean Sea. First, irrigation has expanded in most countries of the Southern Mediterranean zone. In Morocco, for example, 13% of Utilized Agricultural Area (UAA) is equipped with irrigation (High Commission for Planning, 2007). Increasing water scarcity, due both to overexploited aquifers and climate changes, endangers the livelihoods of rural farmers in the Southern Mediterranean countries. In addition, market and processing conditions such as price volatility or storage ability of agricultural products (Lejars and Courilleau, 2014), which depend in turn on multiple factors such as farm type or localization, can accentuate the vulnerability of agriculture and certain social categories of farmers.

Encouraging both a sustainable development of the agricultural sector and lower resource use and impacts, depends, among others, on the availability of functional and accessible services to the greatest number of farmers, and in particular of agricultural advisory services (Dugué *et al.*, 2014). A salient issue affecting the effectiveness of advisory services is the (mis-)match between farmers' expectations (e.g., information, technical advices, innovation, etc.) and the real advices that can be provided (Dugué *et al.*, 2014). In addition, both advisory expectations, requests and services can depend on the diversity of farming systems, including the agro-ecological situations, pedoclimatic conditions, farming systems, and/or access to resources (e.g., financial, water, labor, etc.) (Dugué *et al*., 2014). This requires, at first, that the diagnosis of the specific agricultural and farming situation, its advantages, limits, and possible evolutions, is shared between farmers and the representatives of advisory services.

The case study of Morocco, which is the focus of this study, is of particular interest with regards to advisory services. Indeed, the Moroccan state faced the necessity to reform its advisory service for agriculture, particularly to achieve the goals of the "Green Morocco Plan". In 2011, the state thus initiated a new strategy for its agricultural advisory system, based on three main principles: (1) a diversity of actors involved in the management, implementation and financing of agricultural advisory systems (e.g., including both private and public actors); (2) a scaling down of the advisory services, from national to local, in order to provide a service that could be individual, personalized, and (3) providing farmers with modern technologies for analyses (e.g., soil) and communication to favor the wide dissemination of information, and the possibility of "remote advice" (e.g., consultation of online professional information) (Dugué *et al.*, 2014).

This paper questions how agriculture is perceived by different local actors, namely administration members and farmers. Addressing this question can be performed using different methods and data, e.g., focusing more on direct information (e.g., interviews) or indirect ones (e.g., literature). As individual and collective visions, by definition, evolve through time, we chose to gather information and viewpoints directly with the core actors of the agricultural system. Analysing a collection of oral and qualitative arguments, i.e., *verbatims* requires a method to be able to classify, organize, and compare these arguments. A very common method is the SWOT analysis (Strengths, Weaknesses, Opportunities, and Threats). SWOT generally consists of a list of factors, which can be used to describe the current (corresponding to the SW section of the framework) and possibly future (OT) trends of both internal and external environments describing and/or influencing the studied system (Yavuz and Baycan, 2013). The SWOT analysis thus allows to conduct a situational evaluation (Wickramasinghe and Takano, 2009) to categorize key factors (Nazari *et al.*, 2018). To identify the main themes that SWOT arguments are based upon, the PESTLE approach is a useful tool. This framework has been used in the business and management sectors to monitor the macro-environmental factors that have an impact on the studied system environment (Yudha *et al.*, 2018). PESTLE considers Political, Economic, Social, Technological, Legal, and Environmental classes to categorize sets of factors and facilitate their analysis and comparison. Combining SWOT and PESTLE frameworks hence allows to build a deep insight and understanding on the current realities of a complex problem (Nazari *et al.*, 2018), where visions could differ either in terms of arguments, class, or categorization (e.g., an argument viewed as a strength for one type of actor could be considered as a weakness for another one).

The objective of this study is to compare/confront the visions of practitioners (i.e., farmers) and people responsible for local agricultural administrations (e.g., Regional and Provincial Boards for Agriculture), in order to qualitatively characterize the agricultural sector of a Moroccan agricultural region, namely the Saïss plain.

STUDY AREA

The Saïss plain covers 2,200 km^2, of which about 1,910 km^2 is dedicated to agriculture (Fofack *et al.*, 2015). Climate is of the semi-arid type, and irrigated agriculture has developed since the

1980's and has boomed since the 2000's, leading to a strong decrease in areas dedicated to rainfed crops, and subsequently to a large overexploitation of the aquifer (Ameur *et al.*, 2017a; Quarouch *et al.*, 2014). Irrigated crops (mainly potato, onions, plum and peach orchards, and vineyards) are cropped with a high use of chemical fertilizers and pesticides (Baccar *et al.*, 2018). In 2012, the irrigated area represented approximately 23% of the Saïss plain (Kuper *et al.*, 2016).

SURVEYS AND DATA ANALYSIS

We conducted two series of interviews and meetings with farmers or local administrations to build SWOT diagrams, summarizing their vision of the regional agricultural features. We then mobilized the PESTLE framework to highlight the main themes that were spotted by the two types of actors. The combined SWOT/PESTLE framework was hence used to investigate the current status of agricultural development in the Saïss plain, Morocco, based on the subjective points of view of the two types of actors' interviewees, i.e. two groups of farmers (two cooperatives), and four different local administrations responsible for agriculture.
Note that farmers' viewpoints were more focused on irrigated agriculture, as they all had access to irrigation, while local administration's viewpoints included both rainfed and irrigated agriculture. First, we interviewed individually local stakeholders to gather their viewpoints (in 2018), organized within the SWOT structure. Note that these interviews were performed individually for each structure (Table 1), but that more than one person participated in each interview. Individual SWOT diagrams were then merged and presented in a collective meeting comprising more diverse local stakeholders, for validation and completion. Second, we organized two collective farmers' meetings (in 2019), in which SWOT diagrams were completed by farmers to share their diagnosis with the research team.

Four local administrations responsible for agriculture (extension services) were asked to build a SWOT diagram: the Provincial Boards for Agriculture (DPA) of two provinces (1) El Hajeb and (2) Meknes; (3) the regional Agricultural Council ("Chambre d'Agriculture", CA); and (4) the National Board of advisory services in the agricultural sector (ONCA). These three types of extension services for agricultural development have different functions. While the Provincial Boards focus on subsidies' attribution, local statistics and provide technical assistance for agricultural projects financed by the GMP (e.g., for drip irrigation), the Agricultural Council and the National Board focus more on technical advices and rural development. The ONCA (National Board) was created in 2013 to fulfill the state ambitions of restructuring the advisory system, based on the objectives of the Green Morocco Plan. Its specific mission is to implement the actions of agricultural advice in the whole country (Dugué *et al*., 2014). It is structured with regional, provincial and local levels.

The two groups of farmers, with whom we built the SWOT structure, were located in the rural municipality of Iqaddar, which is a part of El Hajeb Province (within agrarian reform cooperatives of Regraga and Eddakhla, undergoing a privatization process). They are two cooperatives of "medium-sized" farmers (i.e., average of 14 ha and 9 ha for the Regraga and Eddakhla, respectively). Regraga involves 36 farms, and Eddakhla 43 farms (data 2015). For the two cooperatives, the main source of irrigation is groundwater, mainly mobilized with shallow and low yielding wells (69% and 72% for Regraga and Eddakhla, respectively). Regarding the farming systems (data 2015), in the Regraga cooperative, UAA was dominated by rainfed cereals (mainly wheat), market gardening, and forage crops (32%, 24% and 18%, respectively). In the Eddakhla cooperative, the main agricultural uses were cereals (34%), forage crops (21%), market gardening and fallows (18% and 17%, respectively). Livestock production is important for the two cooperatives, justifying the large area dedicated to cereals and forage crops. Eddakhla was created more recently than Regraga (1991 vs. 1972), the last presenting thus a higher parceling out, and more conflicts linked to successions, leading to more land transfers.

The results of the SWOT diagrams built by these two types of actors (local administrations in charge of agriculture / members of advisory boards in the one hand; farmers in the other) were then analyzed both in a quantitative and a more qualitative way. For the former, the analysis was based on the PESTLE framework to highlight the main themes identified by the two types of stakeholders regarding the four SWOT categories. The experts of the research team classified the SWOT factors across the six PESTLE classes (Political, Economic, Social, Technological, Legal, and Environmental). For the qualitative analysis, we illustrated the SWOT/PESTLE analysis with the main issues the actors expressed.

These analyses were performed to (1) compare viewpoints of two types of actors, and (2) identify whether different viewpoints co-existed among each type of actors.

PESTLE arguments

Members of the research team classified the different arguments mentioned by both farmers and local administrations within the PESTLE framework (Table 1). This classification highlighted that Environmental arguments presented the largest diversity (17 different arguments), followed by Technological arguments (3), and the less diverse argument being cited belonged the Legal class (Table 1; Figure 1). The Environmental class arguments included climate, soil, water and the diversity of crops and type of systems of the region. Arguments of all classes were cited by all interviewed actors, except Legal arguments which were cited only by two administrations. While arguments of Economic, Social, Technological and Environmental classes were found in all parts of the SWOT diagram, no Political threat was identified, and no Legal strength or weakness appeared during the interviews.

Table 1. Classification of cited SWOT arguments in the PESTLE classes for all stakeholders. In the column SWOT are indicated the SWOT categories mentioned according to the PESTLE classes (e.g., missing T means that no threat was mentioned).

PESTLE class	Class mentioned by	SWOT class	Arguments
Political	all interviewed	SOW	administrative procedures, agricultural development funds, agricultural policies, "big farmer", infrastructures, subsidies, agropolis*, strengthening ONCA and ONSSA, rural isolation
Economic	all interviewed	SWOT	ecotourism, financial resources, input prices, insurances, investment friendly zone, market access, marketing, "overproduction", production costs, product valuation
Social	all interviewed	SWOT	age of farmers, collective action, coordination between institutions, coordination between farmers, extension, fragmentation of land, labor, land tenure, professional organizations, succession, support/advice

Techno-logical	all interviewed	SWOT	direct sowing, efficacy of products, information, irrigation technics, know-how, mechanization, number of tractors, packaging, productivity related to technique, product quality, storage, valorization unit, yield/level of production
Legal	DPA El Hajeb, CA	OT	standards for export, labeled products (organic, terroir)
Environ-mental	all interviewed	SWOT	arboriculture, climate, climate change, dam (increase irrigated areas), diseases, diversified agriculture, frost, geographical location (close to big cities), livestock and forage resources, low area for livestock, one crop per year, onion country, rain, soil quality, suitable area for crop diversity, water, weeds development

* the Agropolis, located in Meknes (center of the Saïss area), is an industrial zone built to favor agricultural development, with the aim to strengthen the processing and marketing of agricultural products. Its construction was funded by the second pillar of the "Green Morocco Plan; ONCA: National Agricultural Advisory Board; ONSSA: National Office of Food safety.

The overall SWOT/PESTLE diagram showed the dominancy of the classes Environmental, Economic and Social (the two last being almost equivalent) (Figure 1A). However, downscaling to each SWOT compartment gives a rather different picture (Figure 1B). Environmental arguments largely dominated (>50% of the number of arguments) in both Strength (abundant water and very good soil quality being the two most cited) and Threat (climate change/variability and diseases being the most cited) arguments. Environmental arguments were still very important in the Opportunity frame (31% of all arguments, with the climate enabling diversification, and the future dams) and not really considered as a Weakness (although decreasing water quantity and soil quality were mentioned) (Figure 1B). No Legal nor Economic argument were considered as strengths, and Social arguments dominated the Weakness frame (e.g., lack of collective action, of cooperation, difficulty to find extra-workers). Technological arguments were seen more as a Strength (e.g., "know-how", increasing number of tractors) and Opportunity (direct sowing technics, possibility to improve irrigation technics) (Figure 1B).

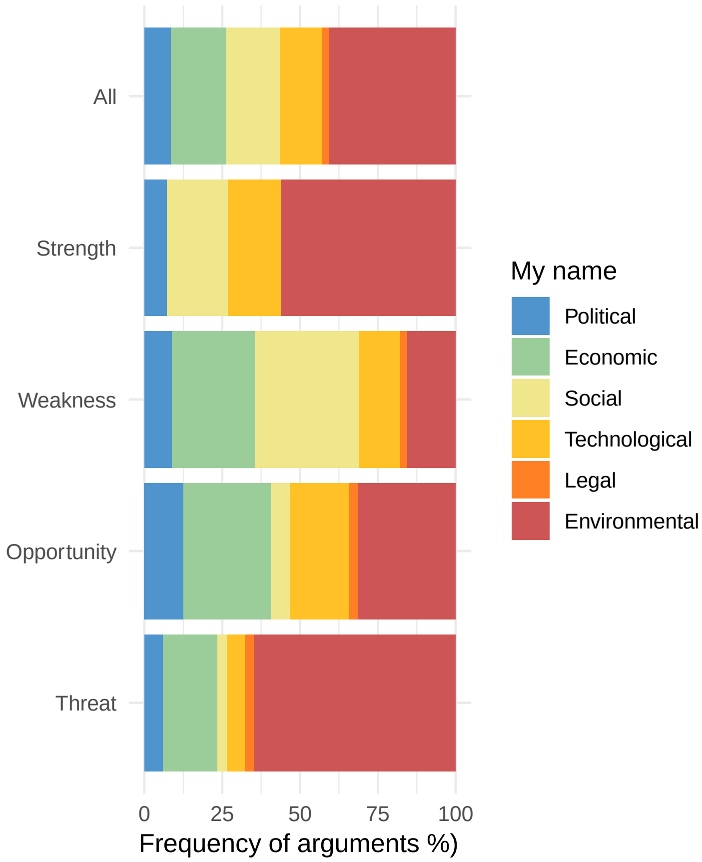

Figure 1. Distribution of PESTLE classes of for all SWOT arguments of the two types of actors (at the top) interviewed and according to each SWOT class.

COMPARISON BETWEEN THE TWO ACTORS' TYPES

Overall, the farmers' cooperatives had a more negative vision of agriculture than the local administrations, with more than 60% of arguments related to weaknesses and threats, and very few opportunities were identified (Table 2). While local administrations listed slightly more weaknesses than strengths, they identified more opportunities than threats.

Similarly, the PESTLE distribution profiles differed between the two types of actors. Legal arguments (Table 1) were cited only by local administrations' representatives, Environmental arguments were more cited by farmers' cooperatives than by local administrations (65.5% vs. 26.8%), and Technological and Social arguments were cited mainly by local administrations (Table 2). Finally, Economic arguments were (surprisingly) cited more by local administrations than by farmers' cooperatives (Table 2).

Table 2. Distribution of SWOT and PESTLE class for the two types of actors.

	SWOT class				PESTLE class					
Actors	S (%)	W (%)	O (%)	T (%)	P (%)	Eco (%)	S (%)	T (%)	L (%)	Env (%)
Farmers	23.6	29.1	14.5	32.7	9.1	14.5	5.5	5.5	0	65.5

Administrations	28.9	29.9	24.7	16.5	8.2	19.6	23.7	18.6	3.1	26.8

S: Strengths; W: Weaknesses; O: Opportunities; Th: Threats; P: Political; Eco: Economic; So: Social; T: Technological; L: Legal; Env: Environmental.

Combining SWOT/PESTLE allowed more insight into the preceding results. Only administrations' representatives identified Economic opportunities, such as ecotourism, new markets (e.g., Africa for onions) or attractiveness for investors. On the opposite, farmers' cooperatives cited many more Environmental weaknesses than the local administrations' representatives: impossibility of growing more than one crop each year, decreasing soil quality, lack of financial resources, and the "water issue" (quantity of water), also identified by one administration (DPA Meknes). Political arguments differed between the two types of actors, with threats (e.g., the "big farmer", rural enclosing) only cited by farmers' cooperatives vs. strengths (subsidies for agricultural development, presence of infrastructures) cited only by local administrations' representatives (Figure 2). This last argument thus appeared as oppositely perceived by the two types of stakeholders.

For the Social arguments, threats were identified only by farmers' cooperatives (lack of good advisory service), and strengths only by administrations (good qualification of workers, food advisory system). Again, this argument opposed the two types of actors. The Social arguments were overall much more developed by local administrations' representatives (Figure 2). Finally, only the representatives of local administrations identified Technological weaknesses (Figure 2), such as a low production level due to a low technicity of farmers and a lack of mechanization.

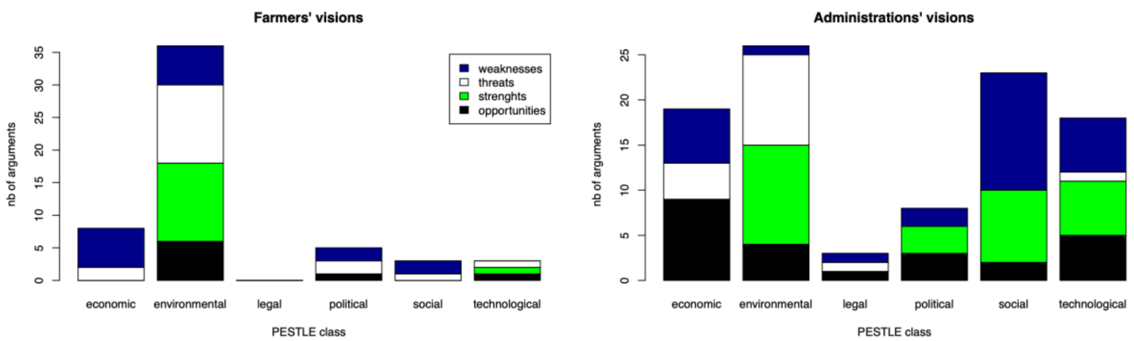

Figure 2. SWOT/PESTLE analysis according to the two types of actors

VARIABILITY OF VIEWPOINTS WITHIN TWO ACTORS' TYPES

The distribution of Strengths, Weaknesses, Opportunities and Threats concerning local agricultural development (specific to irrigated areas and crops) differed between the two cooperatives of farmers (Table 3). The cooperative of Eddakhla highlighted a more pessimistic view of agriculture, with weaknesses and threats representing about 2/3 of the arguments (30.4% and 34.4%, respectively). Both farmers' cooperatives identified several threats, but those of Regraga also foresaw several opportunities (18.8% of all arguments, Table 3). The threats identified by the two farmers' cooperatives related mainly to the Environment class, and concerned the climate issue (i.e., droughts, lower rainfall frequency, climate change, frost), development of pests and diseases, and the overexploitation of deep-water aquifers. While the Regraga members also identified Economic threats (overproduction of onion, commercialization issue), members of the Eddakhla cooperative identified Political (the “big” farmer, and rural enclosing), Social (lack of advisory system) and Technological threats (lack of efficiency of chemical products). Similarly, opportunities identified by the farmers’ cooperatives related to Environmental arguments, mainly regarding the climate (rainfall abundance) which allows a diversity of crops, especially grape and fruit trees. Members of the Regraga cooperative also identified one Political and one Technological opportunity, related to subsidies and technical improvement for irrigation (drip system).

This hence led to different representations in the distributions of Political, Economic, Social, Technological, Legal and Environmental classes between the two farmers’ cooperatives. However, the arguments of type “Environmental” dominated for both cooperatives, followed by Political arguments for the Eddakhla cooperative, and Economic arguments for the Regraga cooperative (Table 3). Surprisingly not dominating, Economic arguments were perceived by Eddakhla members as weaknesses (commercialization issue, lack of funding, high cost production) only, and both as weaknesses and threats by Regraga members (lack of funding, soil quality for the weaknesses, and commercialization issues and overproduction for the threats).

The visions of local administrations’ representative were more equally distributed between Strengths, Weaknesses, Opportunities and Threats (Table 3). The ONCA administration displayed the most different distribution, by identifying more weaknesses than strengths (Table 3). Consistently with farmers’ cooperatives, all local administrations perceived more threats than opportunities in the near future. Threats were also mainly Environmental (climate, resource overexploitation, diseases), Economic (increasing price of inputs, no insurance system, overproduction and difficulty of opening new markets), with one Legal (standards) and one Technological (difficulty to stock perishable products) argument. The opportunities foreseen by local administrations were more numerous and diverse, especially for the Chamber of Agriculture (all PESTLE classes), and less for ONCA (only Economic and Technological arguments). One noticeable opportunity concerned the possibility of attracting new investors, identified by all local administration but the DPA of Meknes.

Regarding the Pestle classes, Legal arguments were identified only by two out of four local administrations (Table 3). These concerned labelling and standards. The other classes gathered arguments consistent between the different stakeholders. Social arguments were listed by the four local administrations. The DPA of El Hajeb was the only one to identify Social opportunities, e.g., land to mobilize, advisory structures. The four administrations identified Social strengths, related to qualified workers, advisory structures, and the presence of research institutes and young farmers. Social weaknesses were also identified by three out of four local administrations (all except the DPA of Meknes). They were the most numerous (57% of arguments of the Social class), and related to the lack of farmers’ organization/coordination, the bad organization of interprofessional structures, the lack of specialized workers, the issue of succession (parceling out of land), and the too low supervision rate.

Table 3. Distribution of SWOT and PESTLE class for the arguments mentioned by the two groups of farmers and the four local administrations

	SWOT class				PESTLE class					
Actors	S (%)	W (%)	O (%)	Th (%)	P (%)	Eco (%)	So (%)	T (%)	L (%)	Env (%)

Coop. Eddakhla	26.1	30.4	8.7	34.8	17.4	13	8.7	8.7	0	52.2
Coop. Regraga	21.9	28.1	18.8	31.2	3.1	15.6	3.1	3.1	0	75
CA	28.6	22.9	28.6	20	8.6	17.1	22.9	14.3	2.9	34.3
DPA El Hajeb	28.6	28.6	28.6	14.3	9.5	14.3	28.6	14.3	9.5	23.8
DPA Meknes	28.6	21.4	28.6	21.4	7.1	28.6	14.3	21.4	0	28.6
ONCA	29.6	44.4	14.8	11.1	7.4	22.2	25.9	25.9	0	18.5

Coop.: cooperative; S: Strengths; W: Weaknesses; O: Opportunities; Th: Threats; P: Political; Eco: Economic; So: Social; T: Technological; L: Legal; Env: Environmental

DISCUSSION AND CONCLUSIONS

DIVERGING PERCEPTIONS OF AGRICULTURAL DEVELOPMENT

The analyses of the SWOT comparison highlighted a higher homogeneity between the visions of local administrations, despite their different roles, than between the two groups of farmers, from two neighboring cooperatives but with divergent perceptions. The main differences between the two farmers' cooperatives could be linked to their history and perception of the future. For instance, the group for which the strengths were less numerous (Regraga) is the oldest one (creation in 1972 vs. 1991 for Eddakhla), in which land conflicts exist, due to succession issues and land fragmentation leading to more land transfer operations. This oldest cooperative was also foreseeing more opportunities, which could be linked to the presence of younger farmers, with more aspirations than the older members of the Eddakhla cooperative. Since the individual land distribution in 1991, these latter members have not had the time to capitalize and individualize their production process, thus remaining trapped in sharecropping processes in order to finance their agricultural activities. These inter-generational specificities have already been identified in this region through a role-playing game developed by Ameur *et al.* (2015). In this study, undertaken in the same area, the authors highlighted that older farmers adopted a "defensive strategy" and were more risk-averse than younger farmers (generally the cooperative's next generation), who look forward to developing a more entrepreneurial agriculture, and explore different futures (Ameur *et al.*, 2015). Regarding the potential opportunities, while the highest presence of investors in the Regraga cooperative could be seen as an opportunity foreseen by these farmers, it was not cited. By grabbing their resources, the "big farmers" have been perceived as a threat by the other cooperatives, in opposition to the view of all local administrations' representatives. For these, they are seen as an opportunity, as they are supposed to achieve the agricultural prowess of the Green Morocco Plan. This may be linked to the dualistic representation of Moroccan agriculture. Even though the Green Morocco Plan is also supposed to support small-scale and subsidence-oriented farming, this dual representation was blamed by farmers, tagging large-sized farms as a threat. The Green Morocco Plan, following the land reform cooperatives, attracted new actors looking for easy profits, among which private urban investors (Petit *et al.*, 2018). Although Petit *et al.* (2018) qualified these as "dilettante farmers [and] not entrepreneurs", their projects have been strongly subsidized. This could explain the farmers vs. administrations viewpoints.

DISCREPANCY AROUND THE ADVISORY SYSTEM

Another main difference between farmers and administrative institutions concerned the advisory system, seen both as a Strength and a Weakness by the institutions (existing training system, but a low number of advisers), while one group of farmers mentioned a complete absence of the advisory sector. This discrepancy is of major importance, as a strong advisory system is an important element for agricultural systems to develop, innovate, and increase their sustainability and resilience (Dugué *et al.*, 2014; Dugué *et al.*, 2015), and to help strengthen farmers' individual and collective capabilities (Baccar *et al.*, 2018). This discrepancy could be linked to the quantitative aspect identified by the local administrations: farmers may not recognize the existence and legitimacy of the (public) advisory system if they do not have access to it. Another reason could be linked to the potential confusion between a public and private advisory system. In the 1980's and 1990's, the disengagement of the Moroccan State led private operators (e.g., suppliers of inputs and agricultural equipment, agro-business structures, etc.) to integrate the agricultural advisory system, especially regarding technical advice (Dugué *et al.*, 2014). This led, in some areas (e.g., non-irrigated), to more regular contacts between farmers and these private advisors as compared to public advisors. More recently, the Green Morocco Plan planned to further integrate this private advisory sector within its policy, by e.g., financing their interventions (as this would be, for the State, more economically efficient) (Dugué *et al.*, 2014). However, part of these interventions could still have to be paid by farmers, thus limiting the scope and impacts of the private advisory sector to the wealthier farmers. Moreover, according to Dugué *et al.* (2015) most family farmers consider that advices have to be free, and would thus be reluctant to fund it themselves. This access to the advisory system could increase the socioeconomic differentiation between farms, already currently very large, and linked to the access to groundwater, land, and more recently to financial capital (Ameur *et al.*, 2017a). This however remains a hypothesis, as the distinction between private and public was made by the local administrations: "public supervision is limited"; while this specification did not appear in the farmers' discourses.

INDIVIDUAL OR COLLECTIVE?

Overall, the social arguments were overall much more developed by the local administrations' representatives as compared to farmers' cooperatives. One main argument developed by both types of actors concerned the collective level, identified as a major weakness (40% of all weaknesses identified globally). These arguments were related to the lack of collective action and organizations of farmers (cooperative functioning, community work, collective crop planning), of professional and inter-professional organizations, but also between the local institutions. Lack of collective actions could hamper the development of agriculture, and even endanger it. For instance, regarding the groundwater depletion and the necessity to install drills to attain confined aquifers (to replace now useless shallower structures), collective funding could be an option to face the impossibility for each individual family farmer to fund this operation. However, the distrust of collective action observed locally prevents such investments, which could moreover be subsided under some conditions (Dugué *et al.*, 2015). Similarly, collective work could allow resource-constrained farmers to increase their production. Although this was observed for some farms in the Saïss region (for the resources: agricultural material, collective work, and knowledge sharing) (Baccar *et al.*, 2018), it is declining (Dugué *et al.*, 2014). Similarly, a collective crop plan could help to face water depletion though a better control of water consumption (Ameur *et al.*, 2018). This lack, and decreasing, will for collective action is due to the history of agricultural land in Morocco, the de-collectivization process being still recent in some areas (e.g., 1991) and imposed cropping patterns remained even after, although land was attributed to individuals (Ameur *et al.*, 2017b). This led to a strong wish of farmers for their autonomy, which involved an individualization process, while, at the opposite, collective work was linked to "a painful state-imposed past" (Ameur *et al.*, 2017b). This independence is both from the state and from fellow assignees, who were enrolled in the collective actions of cooperatives (Petit *et al.*, 2018). However, one can also note a generational gap for this individual vs. collective issue; with young farmers involving themselves more in collective thinking (Ameur *et al.*, 2015).

ENVIRONMENTAL CONCERNS

Finally, one main result of our study concerned the "environmental" vision of the different actors interviewed. First, environmental issues were more significant for farmers' cooperatives than for the local administrations' representatives. Second, these issues were not identified at the same time scale: weaknesses for farmers vs. threats for farmers and administration (e.g., climate change; water scarcity). It is interesting, for instance, that climate change was cited only by two out of four local administrations; while climate variability was cited by only one. These were two main focuses of farmers, cited numerous times during the workshops. This is also true for another environmental issue, i.e., pests, diseases and weeds. These differences could be explained by the time- and space- scales of the two different types of actors involved in this study. While farmers, part of this changing environment, who suffer from depleting groundwater and from the "casino game" type of markets, are continuously expected to pay to update their adaptive strategies (e.g., more capital for deeper drilling), local administrations have a broader vision in space, which is also irregular in time. These differences in time and space observations could be linked to reduced contacts between these administrations and farmers, apart from the subsidizing system (by definition discontinuous in time). Overall, these environmental concerns focus on the productive resources, and their uncertain future, especially with regards to water availability. This could be linked to the phenomenon of exclusion of farmers observed for the irrigated system (Ameur *et al.*, 2017a): as water tables decline, farmers need to invest money that smaller farmers do not have, leading to their marginalization.

CONCLUSIONS

Our study aimed at building SWOT frameworks with two different types of actors, farmers/practitioners and responsibles for local agricultural administrations, represented by two and four groups, respectively. Analyzing those results according to the PESTLE concept, our results highlight discrepancies between visions on different points: the environmental concerns, the role and importance of the advisory system, and the opportunity or danger represented by investors. One common point concerned the lack of current collective action and vision, partly explained by the agrarian history. Surprisingly, the economic issues were more cited by the administrations' representatives than by the farmers' cooperatives. These results highlight different ranking of concerns (both in the SWOT and PESTLE frameworks). This could hamper the efficiency of the agricultural sector to develop and favor the alleviation of poverty, while facing the challenge of limiting rural exodus. To complete this diagnosis study, it would now be interesting to share our results in an enlarged arena of actors, in order to (1) acknowledge/update these results, and (2) elicit and analyze the reasons of the identified differences. This shared diagnosis would then be a first step towards designing more sustainable and resilient agricultural systems for the Saïss region.

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USING TRANSITION ZONES TO RE-THINK BIODIVERSITY-YIELD RELATIONSHIPS IN AGRICULTURAL LANDSCAPES

Kernecker, Maria[a], Pirhofer-Walzl, Karin[b], Paetzig, Marlene[c], Schaub, Larissa[d], Schmidt, Martin[e], Nendel, Claas[f], Meike Fienitz[g]

[a] Leibniz Centre for Agricultural Landscape Research, Germany
[b] Freie Universität Berlin, Germany
[c] Leibniz Centre for Agricultural Landscape Research, Germany
[d] University of Potsdam, Germany
[e] Leibniz Centre for Agricultural Landscape Research, Germany
[f] Leibniz Centre for Agricultural Landscape Research, Germany
[g] Leibniz Centre for Agricultural Landscape Research, Germany

Abstract: Agricultural landscapes have constantly been re-shaped due to changing land use, political structures, and societal demands. The resulting fragmentation has made transition zones between different farming and other land use systems dominant features in agricultural landscapes. Transition zones are areas where two land uses interact. These interactions are shaped by the shared abiotic and biotic gradients, with consequences for biodiversity-yield patterns. Land use intensity can shape transition zones by creating sharp or gradual edges. When investigating the relationship between biodiversity and yield in transition zones, it is impossible to do so without addressing land users, since they make management decisions based on their observations of the environment surrounding land use and property boundaries. Their management decisions affect neighboring land users, and both have to interact with each other, by sharing rights and responsibilities across field and property boundaries that could either correlate or mismatch with ecological spill-over effects. Moreover, different land users may have different priorities for their fields and field edges, with repercussions for biodiversity-yield patterns. Understanding ecological patterns that cross boundaries between land uses and habitats is central to identifying how agricultural land use affects biodiversity-yield relationships across landscapes. Moreover, combining information on ecological patterns with social changes (e.g. shifts in legal boundaries between land uses), could allow for a stronger representation of how land use systems interact within landscapes. Both social and ecological research on transition zones in agricultural landscapes could help shift the paradigm away from a compartmentalized understanding of biodiversity – yield patterns towards considering biodiversity and yield as jointly addressed in management practices for site-specific conditions, especially given the prevalence of transition zones throughout agricultural landscapes. This kind of approach could inform collaborative landscape management practices for achieving desired synergies between biodiversity conservation and food production. Here, we review and discuss transition zones and provide a preliminary road-map of how to research and use these areas for effective landscape integration of different land uses.

CAN POLLINATOR ABUNDANCE BE PREDICTED BY CURRENT AND PREVIOUS LAND USES?

Simone Marini, Tiziana Sabbatini, Sabine Gennai Schott, Anna-Camilla Moonen

Institute of Life Sciences, Scuola Superiore Sant'Anna, Pisa, Italy

Abstract

The alarming global decrease in pollinator abundance and diversity requires an in-depth investigation about the stability of pollinator communities in agricultural landscapes in time. In the Mediterranean basin, the composition of pollinator communities is influenced by human practices, and especially agriculture, but there are few studies which model how pollinator communities respond to land use dynamics. This knowledge can provide important clues for biodiversity-friendly land use planning in agroecosystems based on careful evaluation of land use typology, diversity and dynamics.

Within the framework of the Arimnet2 project DIVERCROP (grant agreement n 618127), we concentrated on the pollinator abundance in order to understand its landscape drivers. In particular, we tested if (i) the abundance and diversity of pollinators in the sampled Semi Natural Habitats (SNHs) is predicted by the land use typology in the sampling year (2013), and if (ii) the abundance and diversity of pollinators depended also on land use dynamics determined by the shift in land use typologies over time (2013-2010).

In 2013, insects have been collected with pan-traps in the Pisa plain using 55 sampling points belonging to 5 SNH typologies (herbaceous areal, herbaceous linear, woody areal, woody linear, fallows) in three sampling times (June, July, September). Insect communities have been analysed using Co-Correspondance Analysis, and analysis of variance of the community distance matrix in response to land use factors was performed.

These analyses highlighted that the land use typology and stability shaped the community of pollinators in the Pisa plain. Many land uses censused in the insect sampling year (2013) contributed to shape the community in that year, and pollinators moved through the landscape following the resources offered by the different crops. When land uses of the previous years have been used as constrained axes in the analyses, it was shown that the overall correlation with the pollinator community was still significant. The land use typology in the sampling year explained the variation in insect abundance best, but the high correlation with land use typology of the previous years suggests that the proportion of perennial land use typologies in the 1km radius landscapes might contribute to explain insect abundance, evidencing that further investigation are necessary.

Introduction

In the last few years an alarm on global pollinator declines was raised by the scientific community (Potts et al., 2010). One of the most discussed anthropogenic causes of the decline is the decreasing quality and quantity of suitable habitat and habitat connectivity following land use changes and intensification of agricultural practices (Senapathi et al., 2017). Bees are the most studied group of pollinators, especially because of their pollination ecosystem service to crops, but also other insect groups (e.g. butterflies, wasp, syrphids etc.) contribute to plant pollination and rely on floral resources (Rader et al., 2016, 2020). Abundance and richness of pollinator communities strongly depend on the suitability of land use patterns (Kennedy et al., 2013, Aguirre-Gutierrez et al., 2015, Rollin et al, 2019), because pollinators like bees and wasps, which are central-place foragers, need flower resources but they are limited in their search range by their body size which affects flight ability (Benjamin, Reilly, & Winfree, 2014). In addition, the majority of bee species and flower-visiting wasps are ground nesters, thus the vegetation composition and management affect the quality of nesting sites present in the landscape (Potts et al., 2005). In this context, it has been reported that areas with wildflowers host more wild bee nests than fallow plots (Cope, Campbell, Grodsky, & Ellis, 2019). Unfortunately, there are few studies investigating how pollinator communities are affected by landscape management and land use change in time (Senapathi et al., 2017).

To improve landscape management aimed at fostering wild pollinator communities, it is necessary to develop models that are able to predict pollinator abundance and diversity from current and previous land use patterns and test if and how land use dynamics determine current pollinator communities. By using landscape-based population-dynamical modelling together with knowledge on the life cycle requirements of pollinators, we can provide information on land use typology, diversity and dynamics to support functional biodiversity (van Rijn, 2017).

In the Mediterranean basin, agricultural practices, species diversity and local food

systems are the complex result of historical and recent drivers which act at the landscape scale. Within the framework of the Arimnet2 project DIVERCROP (grant agreement n 618127), one of the objectives is to illustrate how land use dynamics affect patterns of biodiversity. In this context we analysed the response of key pollinator groups to land use typology and land use change. We hypothesize that perennial land use types are important for wild pollinators since they provide stability in terms of flower resources and nesting sites. In particular, we tested (i) at which moment during the growing season the abundance and diversity of pollinators in the sampled Semi Natural Habitats (SNHs) is best predicted by the surrounding land use typology, and (ii) if the abundance and diversity of pollinators depended also on the shift in land use over time (2013-2010). The answers to these questions support the discussion about best practices in coordination and cooperation at the landscape scale, and more specifically land use patterns in space and time, that can foster farming systems with improved levels of sustainability and resilience in relation to wild pollinator communities.

2. Material and Methods

2.1 Choice of sampling stations

In April 2013, we selected 55 semi-natural habitats (SNHs) in the Pisa plain. The SNHs were chosen according to five typologies, defined based on shape of the element and its woody vegetation cover: woody areal, woody linear, herbaceous areal, herbaceous linear and fallow. Any element longer that 100m, with a width of less than 25m was categorized as linear, otherwise it was categorized as areal. Any element with a woody canopy cover over 30% was categorized as a woody element, otherwise it was considered an herbaceous element. In addition, cropped fields with a temporary vegetation cover (fallows or recently abandoned fields) were classified as substitute of herbaceous areal.

The 55 SNHs were selected inside 15 circular landscape sectors (hereafter named "*block landscapes*") of 1 km radius from a reference sunflower field, having a gradient of SNH cover across the 15 landscapes. The objective was to have 1 SNH for each type in each block landscape, spaced by at least 150m among each other. However, woody areal elements and herbaceous areal elements of adequate size were not always present, forcing to reduce the number of semi-natural habitats in certain landscapes. In this set of SNHs, the minimum distance from the nearest element was 178m, the average 485m, and the maximum distance was 1056m, with an elevation ranging from -4 to 75 m a.s.l..

2.2 Pan traps sampling

Pan traps were made according to Westphal et al. (Westphal et al., 2008). We sprayed 900 plastic soup bowl (400 ml Pro-Pac, Vechta, Germany bowl) with UV-bright yellow, white, and blue paint

(Sparvar Leuchtfarbe, Spray-Color GmbH, Merzenich, Germany). Triplets of bowls of the three different colours were mounted on a single wooden stick forming a pan trap. In each semi-natural element one pan trap was set at the border of the element with a cultivated field, and another one at 12 meters from the border. The two traps were at least 25 meters (diagonally) apart to avoid interference (Droege et al., 2010). Three sampling rounds were carried out following the mean timing of sunflower bloom in the area of study: T1 - two weeks before the beginning of sunflower bloom (from 18 June to 5 July); T2 during sunflower bloom (from 18 July to 25 July); T3 four weeks after the end of sunflower bloom (from 19 September to 26 September).

The pan traps were placed at vegetation height and they were filled by approximately 350ml of water with a drop of detergent. Each pan trap was left active for four days.

The collected insects were extracted and classified in the subsequent groups (either Classes or Families or single species): Lepidoptera (butterflies and moths) , Syrphidae (hoverflies), Dolichopodidae (long-legged flies), Empididae (dagger flies), Vespidae (wasps), honey bees (*Apis mellifera* L.) and wild bees (Apoidea: Apiformes, excluding honey bees).

2.3 GIS data

The core of GIS data was extracted from the Tuscany Agency for Agricultural Payments (ARTEA), which trace the agricultural land uses year after year, including the crop, in each parcel of land. Data about urban areas, woodlands and infrastructures, as well as river courses and lakes, were extracted from the Web Map Service (WMS) Geoscopio of the Tuscany Region. The few areas for which land use could not be classified with the two above mentioned systems were identified and classified through visual observations of aerial photographs. Five sites were excluded because they still had more than 33% missing land use data. In total, data from 50 sites were included in the analyses.

The resulting 50 shapefiles, one per sampling point, were cleaned from topological errors using GRASS GIS (GRASS Development Team, 2016) algorithms and rasters of 1 square map unit (i.e. 1 square meter) were computed using SAGA (Conrad et al., 2015) classifying the land uses as described in Table 1.

The total area of each land use per raster was computed using the function *lsm_c_ca* from the R package *landscapemetrics* (Hesselbarth, Sciaini, With, Wiegand, & Nowosad, 2019) in R 3.4.4.

Table 1: *Land use classes used in this study, and a brief explanation of each class. Land use data were estimated in 1 km radius around all the 55 Semi-Natural Habitat sites selected in the countryside of Pisa, Italy, using data from from Tuscany Agency for Agricultural Payments (ARTEA) and Web Map Service (WMS) Geoscopio of the Tuscany Region.*

Class	Description
Non habitat	Water courses, lakes, roads
Urban area	Urban areas including farming buildings and sport areas.
Urban green	Green areas including public gardens and private gardens
Grain cereals	Oats, spelt, wheat, durum wheat, millet, barley, rye, switchgrass, triticale
Sunflower	Sunflower
Grain legumes	Common bean, faba beans, chickpea, soya bean

Feed pastures legumes	Alfalfa, Italian sainfoin, trefoil, vetch
Feed pastures others	Non-legumes grasses, as well as agricultural meadows and pastures
Vineyard	Vineyards
Maize	Maize
Commercial horticulture	Commercial horticultures
Vegetable garden	Vegetable gardens managed by families
Commercial woodland	Planted woodlands for commercial purposes
Long term rotational	Long term rotational fields
Herbaceous SNHs	Channel banks, grasslands
Olive grove	Olive groves
Fruit trees	Fruit trees such as apricots, peach, pear…
Other grain crops	Flax, sugar beat, sorghum
Bare ground	Plough arable land
Rapeseed	Rapeseed
Nursery	Nurseries

2.4 Data analysis

Data analysis was performed using R 3.4.4. In order to deal with the non-linearity of the unconstrained variables we built CCA (canonical constrained correlation) models using the function *cca* from package *vegan* (Oksanen et al., 2016). The constrained (environmental) variables were selected using the criteria of variance inflation factor (VIF) in two steps. Firstly, for each year's land use set (i.e. 2010, 2011, 2012, 2013), a recursive computation of VIFs was performed excluding at each cycle the variable having the highest VIF, until all the environmental variables had VIF < 4. Secondly, only the land uses in common among the 4 VIF analyses were kept: this subset of land uses was used as environmental variables.

In order to test hypothesis one, we built three sampling time models (CCA June, CCA July and CCA September) using pollinators' community composition of each sampling round in 2013 as unconstrained variable. In the models, the abundance of each pollinator group was the mean of insect abundance for the two pan-trap triplets set per sampling site. The constrained (environmental) variables were the land use types retained in the subset for 2013. Distance matrices were computed using Bray-Curtis index which is appropriate for detection of underlying ecological gradients (Faith, Minchin, & Belbin, 1987). In order to test the significance of constrained axes, we performed an ANOVA-like permutation test for the three CCA models, using the function *adonis2* from package *vegan* (Oksanen et al., 2016) which fitted linear models to distance matrices using a permutation test with pseudo-F ratios.

In order to test hypothesis two, we built four models (CCA 2013, CCA 2012, CCA 2011 and CCA 2010) using the community composition of sampling round one (June) as unconstrained variable and the constrained (environmental) variables were the land use typology subsets for each year (2013, 2012, 2011 and 2010). Distance matrices were computed using Bray-Curtis index.

3. Results

The three sampling time models significantly explained the variation in community composition: CCA June [F(12, 33) = 2.23, p = >0.001], CCA July [F(12, 33) = 1.98, p = 0.004], and CCA September [F(12, 30) = 2.98, p = >0.001],. The Inertia explained by constrained axes was the highest using the community composition of September (CCA September, 54.4%), while the lowest Inertia explained by constrained axes was obtained using community data of July (CCA July, 41.8%; Table 2).

Table 2*: Canonical correspondence analysis (CCA) model summaries for pollinator community composition collected using pan-traps, and land use types estimated in 1 km radius around the 50 selected sites in the countryside of Pisa, Italy. In the three models, the estimated land use data are used as canonical axes.*

	CCA June		CCA July		CCA September	
	CCA1	CCA2	CCA1	CCA2	CCA1	CCA2
Eigenvalues	0.237	0.137	0.214	0.183	0.300	0.130
Cumulative variance explained	0.227	0.359	0.173	0.321	0.313	0.448
Specie-environment correlation	0.874	0.708	0.810	0.709	0.910	0.741
Total Inertia	1.043		1.238		0.961	
% Inertia explained by constrained axes	44.7%		41.8%		54.4%	

The land use types that significantly influenced community composition in the three sampling times in 2013 are listed in Table 3.

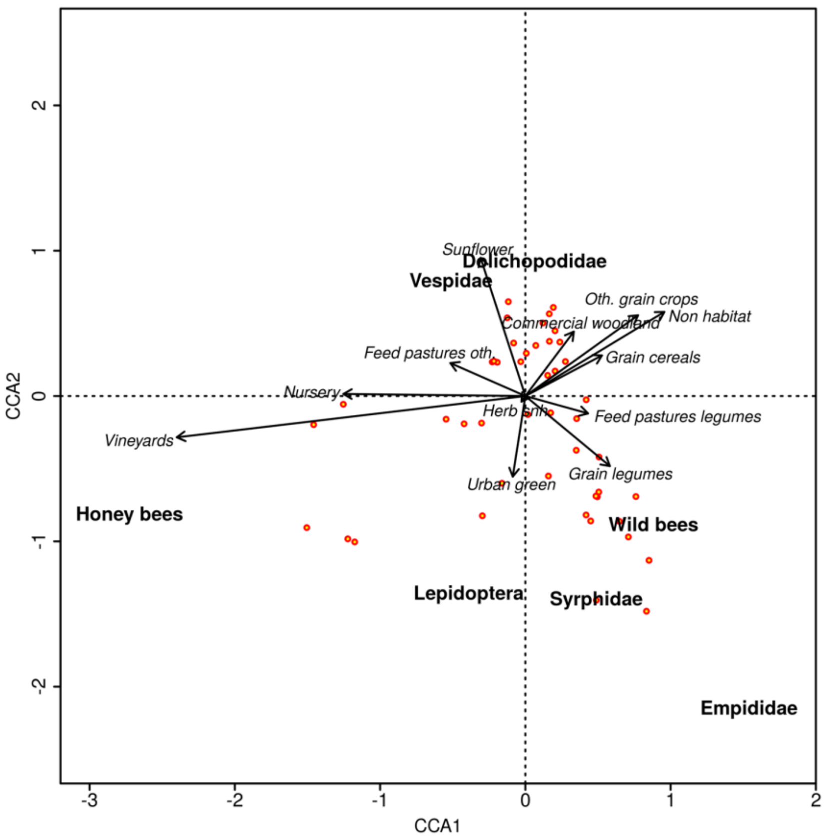
Table 3*: Significant land use typologies in a 1 km radius (in the three sampling times in 2013 – June, July and September) explaining the similarity matrices of pollinator community composition collected using pan-traps in 50 selected sites in the Pisa plain, Italy.*

	CCA June					CCA July					CCA September				
	Df	SS	R2	F	p	Df	SS	R2	F	p	Df	SS	R2	F	p
Non habitat	1	0.21	0.02	1.28	0.278	1	0.16	0.02	0.89	0.507	1	0.39	0.05	2.80	**0.015 ***
Sunflower	1	0.43	0.05	2.65	**0.021 ***	1	0.35	0.04	1.88	*0.071* .	1	0.15	0.02	1.10	0.352
Grain legumes	1	0.46	0.05	2.83	**0.018 ***	1	0.66	0.07	3.58	**0.001 ** **	1	0.07	0.01	0.54	0.790
Feed pastures other	1	0.40	0.04	2.45	**0.033 ***	1	0.18	0.02	0.96	0.466	1	0.16	0.02	1.16	0.320
Vineyards	1	0.52	0.06	3.22	**0.009 ** **	1	0.27	0.03	1.46	0.182	1	0.40	0.05	2.91	**0.014 ***
Herbaceous SNH	1	0.18	0.02	1.13	0.355	1	0.35	0.04	1.88	*0.072* .	1	0.48	0.06	3.42	**0.005 ** **
Other grain crops	1	0.21	0.02	1.29	0.264	1	0.07	0.01	0.39	0.911	1	0.34	0.04	2.48	**0.030 ***
Nursery	1	0.50	0.06	3.06	**0.010 ***	1	0.13	0.01	0.68	0.699	1	0.24	0.03	1.69	0.125
Residual	33	5.38	0.60			33	6.11	0.66			30	4.17	0.54		
Total	45	8.90	1.00			45	9.21	1.00			42	7.69	1.00		

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

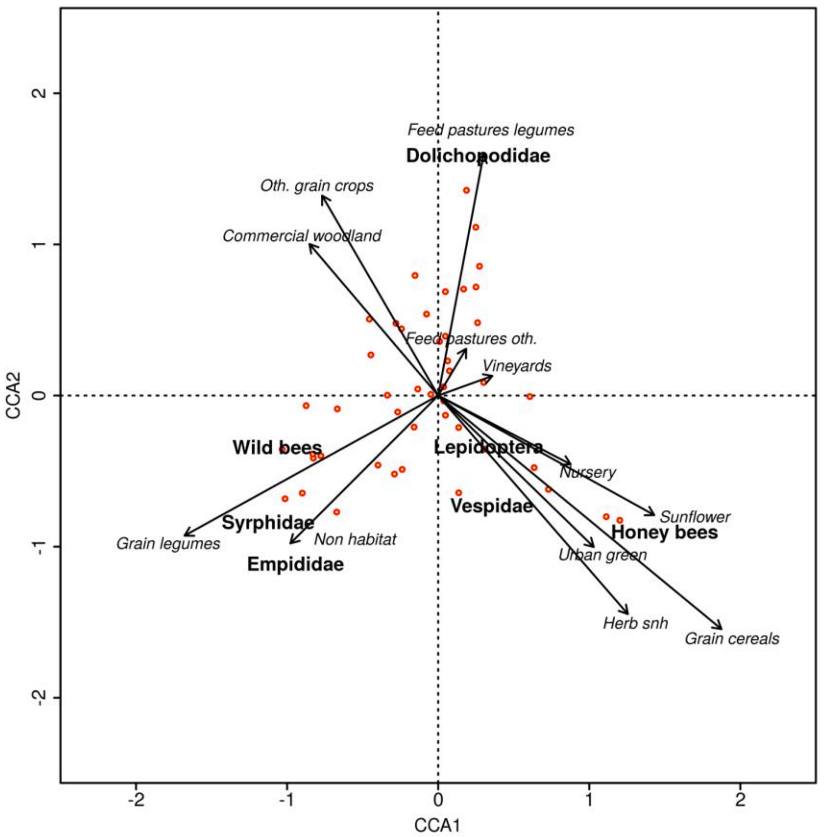
Sunflower and grain legumes explained the variation in community composition in June and July (Table 3). Sunflower correlated positively with long-legged flies and wasps in June (Figure 1.a), while in July sunflower correlated positively with honey bees (Figure 1.b). Instead, grain legumes correlated positively with wild bees, hoverflies and dagger flies in both sampling times (Figures 1.a, 1.b). Later, in July and September, herbaceous SNHs explained the variation in community composition (Table 3) and correlated positively with butterflies, wasps and honey bees in July (Figure 1.b), and with butterflies and long-legged flies in September (Figure 1.c). Differently, vineyards were significant in June (Table 3), correlating positively with honey bees (Figure 1.a), and in September, when they correlated positively with butterflies. In addition, in June, other feed pastures and nurseries were significant (Table 3) and negatively correlated to wild bees, hoverflies, dagger flies and butterflies (Figure 1.a). In September, long-legged flies were more abundant in landscapes with commercial woodland, and wild bees, honey bees and wasps were dominant in landscapes with grain cereals and grain legumes, which are covered with spontaneous vegetation at this point in time (Table 3 and Figure 1.c).

a)



Sunflower
Dolichopodidae
Vespidae
Oth. grain crops
Commercial woodland
Non habitat
Feed pastures oth.
Grain cereals
Nursery
Herb snh
Feed pastures legumes
Vineyards
Grain legumes
Urban green
Honey bees
Wild bees
Lepidoptera
Syrphidae
Empididae
CCA1
CCA2

b)



Feed pastures legumes
Dolichopodidae
Oth. grain crops
Commercial woodland
Feed pastures oth.
Vineyards
Wild bees
Lepidoptera
Nursery
Vespidae
Sunflower
Syrphidae
Honey bees
Grain legumes
Non habitat
Urban green
Empididae
Herb snh
Grain cereals
CCA1
CCA2

c)

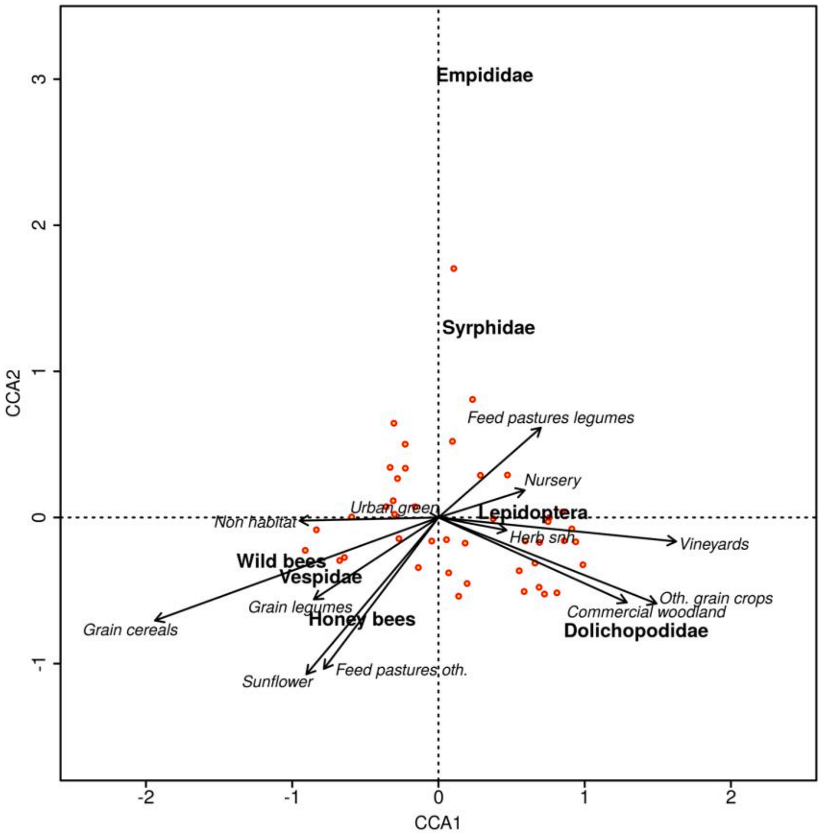


Figure 1: Canonical correspondence analysis (CCA) ordination bi-plot of land use types (arrows) estimated in 2013 in 1 km radius around the 50 selected sites in the countryside of Pisa and community composition collected using pan-traps in June (a), July (b), and September (c). Scaling on species.

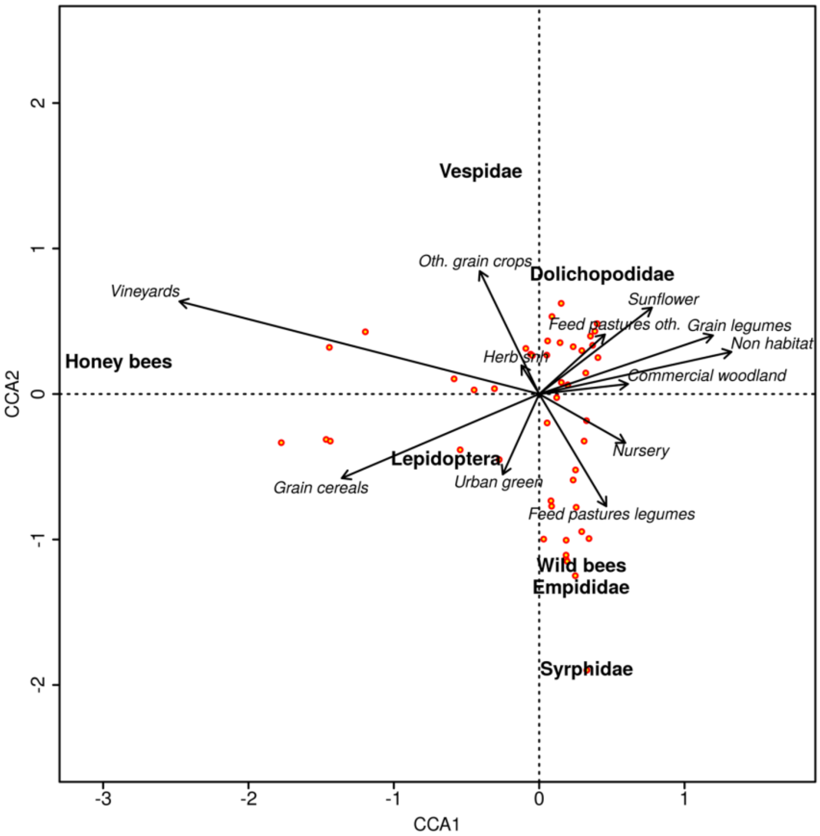
The land use data from the sampling year (2013 [F(12, 33) = 2.23, p = >0.001]) and the previous years (2012 - [F(12, 33) = 2.03, p = 0.003]; 2011 - [F(12, 33) = 2.01, p = >0.001]; 2010 - [F(12, 33) = 1.78, p = 0.009]) are all highly significant to explain the variation in insects abundance. The explanatory power of the land use typologies for the four models is listed in Table 4, while Fig. 2 shows the bi-plot of CCA 2011 model including pollinators and constrained environmental axes.

Table 4: Canonical correspondence analysis (CCA) model summaries for community composition of insect pollinators collected in June 2013 using pan-traps, and the extracted land use types for each year (2010-2013) in 1 km radius around the 50 selected sites in the Pisa plain, Italy. In the four models, one per year, the land use data for each year are used as canonical axes.

	CCA 2013		CCA 2012		CCA 2011		CCA 2010	
	CCA1	CCA2	CCA1	CCA2	CCA1	CCA2	CCA1	CCA2
Eigenvalues	0.237	0.137	0.223	0.122	0.209	0.136	0.234	0.090
Cumulative variance explained	0.227	0.359	0.214	0.331	0.200	0.331	0.225	0.311

Specie-environment correlation	0.874	0.708	0.858	0.679	0.842	0.704	0.869	0.614
Total Inertia	1.043		1.043		1.043		1.043	
% Inertia explained by constrained axes	44.7%		42.4%		42.2%		39.3%	

Figure 2: Canonical



correspondence analysis (CCA) ordination bi-plot of land use types (arrows) estimated in 2011 in 1 km radius around the 50 selected sites in the countryside of Pisa and community composition collected using pan-traps in June 2013. Scaling on species.

4. Discussion

Land uses contributed differently to explain the pollinator community composition throughout the season in 2013, confirming the first hypothesis. In all the three sampling rounds land use significantly explained the abundances among the pollinator groups. In September, the correlation between land use and pollinators was higher than in July (Table 2). Despite the fact that we only analysed the total number of individuals belonging to each pollinator group without taking into account in species composition, the variation explained by constrained axes was high. This shows that species belonging to these groups had similar needs in summer.

In July sunflower correlated positively with honey bees (Figure 1.b), which can be explained by the fact that in the sampling area, just before sunflower bloom, in July, beehives are actively placed in the surroundings of sunflower fields in order to produce honey and pollinate sunflower.

This may explain why we found more bees where the surface of sunflower in the area was higher. However, it is not clear why sunflower correlated positively with long-legged flies and wasps in June (Figure 1.a). Many larvae of long-legged flies nest in the soil or in decaying plant material, especially in semi-aquatic habitats (Pollet, 1992) and their abundance and diversity in these habitat is similar to that found in reed marshes, their preferred environment (Pollet, 2001). In our sampling area, the highest surface of sunflower fields is present in reclamation lands. This might imply that, earlier in the season, long-legged flies might reproduce nearby sunflower fields, in ditches or swamps, and then swarm in sunflower fields to feed on nectar and soft-bodied insects found on sunflower plants and its weeds (Kautz & Gardiner, 2019). An alternative hypothesis might be that Dolichopodidae, during the winter and early spring, directly use the undisturbed soil in future sunflower fields to reproduce, and then they stay there as adults until other flower resources are available. Later in the season, herbaceous SNHs and other grain crops seem to be important for long-legged flies. These habitat may provide flower resources to feed on.

Wild bees, hoverflies and dagger flies were more abundant in SNHs surrounded by grain legumes in June and July (Figures 1.a, 1.b). In the study area, grain legumes are composed mainly by soya beans and faba beans. We suppose that, while wild bees might have been favoured earlier by grain legumes, when those crops bloomed (around April) and then established their nests nearby, hoverflies and dagger flies might predate the aphids in the these crops after blooming. On the other hand, other feed pastures and nurseries negatively correlated to wild bees, hoverflies, dagger flies and butterflies in June (Figure 1.a). Before June, feed pastures are mown in order to produce hay. In landscapes with a high percent cover of feed pastures and nurseries the lack of resources might have distracted these pollinators from the landscape, forcing these highly mobile insects to find food elsewhere. Later, in September, non habitat positively correlated with wild bees, as well as honey bees and wasps (Figure 1.c). Non habitat comprises water courses, lakes and roads, thus on banks and road sides, pollinators might have found flower resources and nesting sites in a moment when crops are not blooming (Hevia et al., 2016).

In the study area, vineyards are a intensively managed crop, sprayed especially with fungicides. However, often weeds are not completely removed, and management consists in regular mowing. The usual vineyard management might explain the positive correlation with honey bees in June (Figure 1.a), and the positive correlation with butterflies in September (Figure 1.c). These pollinators may have been attracted by the flower resources provided by the spontaneous vegetation in the vineyards.

The variation in abundance of insects belonging to the key pollinator groups, sampled in 2013, was significantly correlated to land use data from all 4 years (2010-2013), . This may be explained by the fact that land use in the study area is partly composed of perennial crops and non-agricultural areas, offering a stable habitat to insects.

As expected, the land use data from 2013 provides the highest correlation with the pollinator community, as shown by the highest percentage inertia (44,7%) explained by constrained axes and species-environment correlation of the first CAA axes (Table 4). The percentage inertia explained by constrained axes using data from the years 2012 and 2011 is only slightly lower than that of 2013(42.4% and 42.2% respectively). The higher inertia explained by constrained axes up to 2011 model, may be explained by the common simple rotation used in the study area, where often wheat and sunflower alternate. In fact, in 2013, sunflower explained very well the insect assemblage in sampling rounds 1 and 2 (Table 3), and it is very likely that many of the sunflower fields in 2013 were also sown to sunflower in 2011 explaining the position of long-legged flies in Figure 2. On the other hand, the crop stability through the years may provide a benefit to the insect community and this is confirmed by the stable correlation of the insect community composition in 2013 in relation to land use composition in the previous years. Another clue supporting this hypothesis is in Figure 2, where the land uses closer to pollinators groups are often the more stable ones, such as urban green areas, vineyards and feed pasture legumes (mainly composed by alfalfa which has a mean crop cycle of three years in the study region) which are near to butterflies, honey bees, wild bees, dagger flies and hoverflies, respectively. However, the analyses presented do not fully prove our second hypothesis, but the high correlation between pollinator community composition with land use data from the three previous years evidences the need of further investigation in order to better understand the importance of perennial land use types in intensively managed agroecosystems.

The next step will be to analyse the land use dynamics in each focal landscape to determine if the correlation between pollinator communities and past land use typologies is better explained by the proportion of land use typologies in a focal landscape or by the stability or turnover of land use. On the one hand, this information can help us to predict pollinator community abundances and diversity based on past land use data, and on the other hand it helps to increase knowledge about the responses of pollinator communities to land use changes, especially differences between landscapes dominated by perennial and annual vegetation.

5. Conclusion

These analyses highlighted that the land use typology and dynamics at a relevant landscape scale for mobile wild pollinators shaped the community of pollinators collected with pan traps in the Pisa plain. Many land uses censused in the insect sampling year (2013) contributed to shape the community in that year, and pollinators moved through the landscape following the resources offered by the different crops. This provides strong support for the importance of spatial crop diversification to foster pollinator communities throughout the year. When land uses of the previous years were correlated to the pollinator composition, the results demonstrated that although part of the crops changed position in the landscape, the overall correlation with the pollinator community was still significant. We can conclude that a high proportion of perennial vegetation is important and can provide stable habitat to pollinators. It is no surprise that the land use typology in the sampling year explained the variation in insect abundance best, but the high correlation with land use typology of the previous years suggests that the proportion of land use typologies in the 1km radius landscapes were not changing much over time. In order to confirm this hypothesis a deeper data analysis is needed. The results of this study, and further investigation, can help to determine the importance of perennial habitats and land use mosaics to support pollinator communities.

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FARMERS' ROLES AND PERCEPTIONS AS CONTRIBUTION TO THE CO-DESIGN OF INSECT-FRIENDLY FARMING SYSTEMS AT LANDSCAPE LEVEL

Maria Busse[a], Felix Zoll[a], Rosemarie Siebert[a]

[a] Leibniz Centre for Agricultural Landscape Research (ZALF), Germany

Abstract

Insects play a crucial role for the functioning of our ecosystem but they are decreasing in numbers and variety. Agricultural landscapes, which cover more than half of Germany's total area, can provide vast insect habitats if they are managed accordingly. So far, there is a lack of implemented insect-friendly farming systems, which calls for accepted solutions. However, little is known about stakeholders' perspectives concerning their problem awareness, attitudes, current behaviour, or possible solutions. The project aim is to jointly develop insect-friendly farming systems at landscape level that are beneficial for insects and economically viable, e.g., through the establishment of flowering bioenergy crops. By involving agri-ecologists, entomologists, social scientists, and stakeholders (farmers, landowners, farmers associations, advisory services, nature conservation organisations, decision-makers, etc.) the project initiates an integrative and collaborative process with iterative feedback-loops. In this paper, we present the empirical results of an actors' analysis (constellation and roles) and evaluate actors' perceptions and visons. We use semi-structured interviews to collect data and qualitative content analysis for data interpretation. Preliminary results include: (1) competing perceptions and values exist among stakeholders (pro-active and open-minded actors vs. sceptical actors); (2) ecosystem services provided by insects play a minor role for farmers; and (3) some farmers feel that the image of agriculture has been tarnished by insect biodiversity discourses. The discussion of our results is complemented with media publications on the issue. Finally, the results are valuable for the next steps of the co-design process, especially for the development of suitable insect-friendly measures at landscape level. Generally, the project outcome is embedded in the broader challenge to contribute to the initiation of a system change that encourages a rethinking of the current agricultural system and supports establishing an innovation niche.

Introduction

Insects play a crucial role for the functioning of our ecosystem in general and in agricultural landscapes in particular, for example providing pollination or natural pest control (Isaacs et al. 2009). However, insects are decreasing in numbers and variety. Intensification and simplification processes in agricultural landscapes and associated practices such as the use of agro-chemicals and pesticides, the deterioration of water bodies through fertilization or frequent cutting of grassland removing floral food sources of insects, result in a loss of habitats for insects and numerous other species (Grass et al. 2016; Potts et al. 2009). Consequently, the provision of the insects' ecosystem services decreases (Ekroos et al. 2014). Agricultural landscapes, which cover more than half of our planet's surface, can provide vast insect habitats if they are managed accordingly. To restore and foster biodiversity, it is therefore important that measures do not just concentrate on protected areas. Instead, insect-friendly measures have to be extended to a landscape level and should be carried out in production areas and the surrounding green infrastructure (Batáry et al. 2011). So far, there is a lack of implemented insect-friendly farming systems, which calls for the development of suitable solutions. However, little is known about actors' perspectives concerning their problem awareness and attitudes towards the insect biodiversity decrease, current farming practises or alternative acceptable solutions. However, the consideration of multiple actors, their diverging interests and concerns about landscapes is needed to legitimize decisions but also to generate suitable outcomes (Reed et al. 2009). Knowing the actors' roles and applying adequate participatory strategies (e.g. involving important actors actively in the development of solutions) supports that solutions are place-based, applicable, and accepted by the actors (Campellone et al. 2018; Zscheischler, Rogga, and Busse 2017; Lange, Siebert, and Barkmann 2016). Such a co-design process is in line with adaptive and collaborative landscape design and management approaches (Folke et al. 2005; Olsson, Folke, and Berkes 2004; Campellone et al. 2018). Co-design describes the collaboration between scientists and lay people (practitioners, decision-makers, etc.) in flexible and iterative processes with feedback loops (Meynard, Dedieu, and Bos 2012). Farmers and other actors should not be seen as mere recipients of inventions but as proactive co-developer of innovations (Meynard, Dedieu, and Bos 2012; Reed 2008).

To cope with the challenge of a decreasing insects biodiversity in agricultural landscapes and to address the requirements of actors involvement in the research process, the project 'FInAL' (FInAL - Facilitating insects in agricultural landscapes through renewable resources) has been initiated. The project aim is to jointly develop insect-friendly farming systems at landscape level that are beneficial for insects and economically viable, e.g., through the establishment of flowering bioenergy crops. For that purpose, landscapes labs will be established (see figure 1). By involving agri-ecologists, entomologists, GIS and monitoring experts, agri-economists, sociologists, and practitioners (e.g., farmers, landowners, farmers associations, advisory services, nature conservation organisations, decision-makers) FInAL is a real transdisciplinary (TD) project. The pilot phase of the project is being funded from 2018 until 2021. Nevertheless, there are attempts for a long-term funding to perform a sustained monitoring and assessment regarding the appropriateness of the farming system and to implement tested measures in other agricultural landscapes beyond the established landscape labs.

Whereas the overall FInAL project is dedicated to a broad bundle of ecological and socio-economic research questions, in this paper we focus on research questions related to the initiation phase of the co-design process from a sociological perspective:

RQ1: Who are the relevant actors in the landscape lab and what are their roles?

RQ2: What are the perceptions and visions of farmers' for establishing insect-friendly farming systems?

Material and Methods

Approach: Landscape labs

To elaborate farming systems at landscape level, the FInAL project uses the so-called 'landscape lab' approach. In the landscape labs innovative insect-friendly farming systems will be tested (including an interdisciplinary monitoring and evaluation) and implemented to promote fundamental and long-term changes in the agricultural production system. The landscape labs are located in specifically selected agricultural regions and cover an area of three per three kilometres each. The size reflects the mobility radius of bumblebees. The approach of landscape labs is based on a holistic landscape perspective that includes farm plots and the surrounding landscape infrastructure (e.g., semi-natural habitats) instead of focussing merely on single farm plots or individual farms. At the current state, the FInAL project focuses its activities on two landscape labs which will be implemented in two intensively used agricultural landscapes with conventional farming practices. Both landscape labs are located in Northern Germany (see fig.1). The first landscape lab is located in the Federal state of Brandenburg. Here, mainly intensive grassland production takes place. The region is characterized by big farms and plots. The second landscape lab is located in the Federal State Lower Saxony. Due to the fertile soil, the production focus is on crops and only to a marginal extent on grassland. The farms and plots are medium-sized.

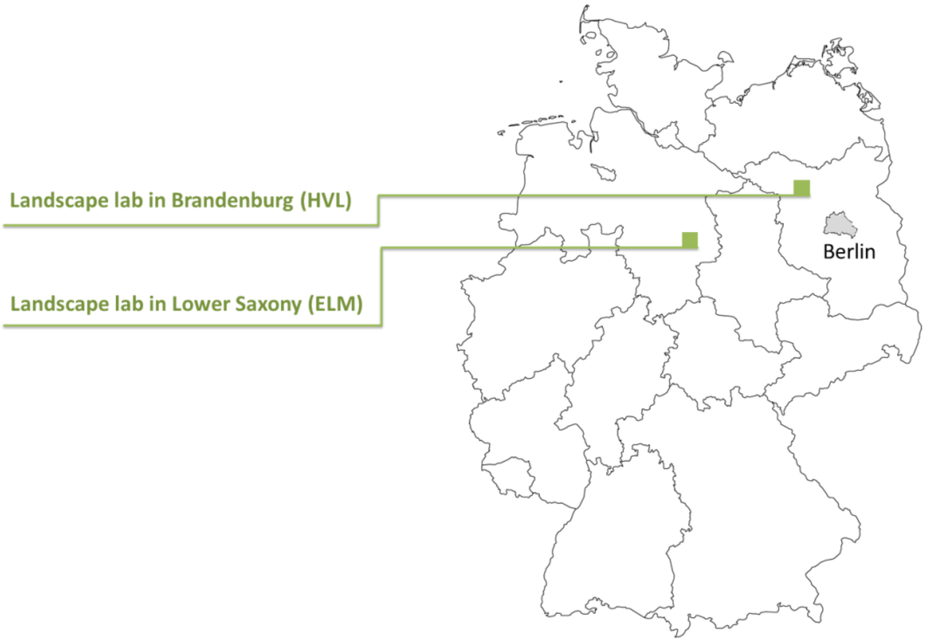


Figure 45: Location of the future landscape labs in Germany

Methods: collecting and analysing data

The design of insect-friendly farming systems in agricultural landscapes can be understood as contemporary complex phenomenon in a real-life context. Most aspects of the issue are new and still unknown. Thus, we applied an explorative and qualitative research approach, which is mentioned in the literature as being suitable for such phenomena (Patton 2019).To identify the actors' constellation and roles (RQ1), we conducted informal interviews with our partners in practice in 2018, held an informative workshop in one of the landscape lab regions in May 2019, and asked in the qualitative semi-structured interviews (Patton 2019) about additional actors applying the snowball principle. The outcome of the analytical process is a matrix with the actors' constellation, their roles, and the strategy for their involvement in the co-design process. Actor or stakeholder analysis is an important and often used method in multi-actor contexts to systemize empirical data on actors, to get an overview on the situation in the case study area, and to derive adequate participatory strategies (Reed et al. 2009; Hermans and Thissen 2009).

We used these semi-structured interviews to analyse the perception and visions of the actors which were mainly farmers (RQ2). In the landscape lab HVL, we conducted 3 interviews with farmers and 2 interviews with other land managers. In the second landscape lab, we performed 19 interviews with farmers and 1 interview with a private nature conservation organisation. The interview guideline was based on own previous knowledge from similar projects, established literature, and the informative workshop. The guideline contained questions about 1) the perception of insect decrease; 2) the importance of insect biodiversity for the farm and region; 3) existing insect-friendly measures on the farm or the managed land; and 4) the requirements for the development of insect-friendly farming systems. The interviews lasted between 30 minutes and one-and-a-half hours. To meet the requirements of transparency and reliability in qualitative research (Patton 2019), we produced interview notes, which included the personal impression and circumstances of the interview situation, as well as additional information beyond the recorded interview itself. The audio-recorded interviews were transcribed. Afterwards, the transcripts were sent to interviewees, thus providing them with copies with which to confirm the interview content. This procedure follows the ethical standards of qualitative social science (Mero-Jaffe 2011).

To analyse and interpret the semi-structured interviews, we used the method of qualitative content analysis described in Kuckartz (2014) and Schreier (2014). Recognizing that there are diverse types of qualitative content analysis, we applied the structured type to perform an interpretive thematic analysis. For this type, the use of thematic categories is common. Whereas the main topics are developed deductively (from the interview guideline), the specific thematic categories were built inductively. Inductively means that the categories stem from the empirical material. This approach is often applied when the phenomenon is novel and categories are unknown.

Results

Results of RQ1:

Both landscape labs vary in their number of farms and individual farm sizes. Due to the agricultural structure in the HVL region, in this landscape lab only a few farmers are active. In contrast, the area of landscape lab ELM is cultivated by 24 farmers (Table 1). Both lab regions have water and ground organisations that represent the interests of owners and users, regional nature conservation authorities, biogas plants, other administrative organisations, and local residents. In contrast to the lab region ELM, in HVL there is no official agricultural advisory service.

Table 27: Relevant actors in the landscape labs and their roles

Actor category	Actors in landscape lab HVL	Actors' roles in HVL	Actors in landscape lab ELM	Actors' roles in ELM	Participatory strategy per actor category
Agricultural users	8 farms and farm manager	Mostly conventional agricultural activities, 2 farms cover the main part of the area	24 farms and farm manager	Conventional agricultural activities, 5 farms cover the main part of the area	Active involvement in the co-design, implementation, and dissemination of measures
Other land users and managers	Regional water and ground association	Organisation of public interest, maintenance of water bodies and riparian stripes	Regional ground association 'Feldmarksinteressentschaft'	Community of interest of land owners, maintenance of waysides and field margins	Active involvement in the co-design, implementation, and dissemination of measures
	District administration	Organisation of public interest, maintenance of waysides			Active involvement in the co-design, implementation, and dissemination of measures
			Private forest owners	Management of forests	Informed about project progress
	Private hunters	Hunting	Private hunters	Hunting	Informed about project progress

Agricultural advisory	---	---	Regional chamber of agriculture	Advisory services, experimentation	Involvement in the dissemination of measures and setting-up policy recommendations
Nature conservation	Regional nature conservation authority	Decisions regarding impact mitigation regulation and species and habitat protection measures, etc.	Regional nature conservation authority	Decisions regarding impact mitigation regulation and species and habitat protection measures, etc.	Involvement in setting-up policy recommendations
	Regional governmental ornithological centre	Research and monitoring of protected species	Private nature conservation organisation	Land owner of several land plot	Informed about project progress
Renewable energy	1 Biogas plant operator	Production of biogas, external company using mainly regional substrate	2 Biogas plants operator	Production of biogas, managed by local farmers using regional and supra-regional substrates	Involvement in the co-design and implementation of measures
Business	Regional agricultural trading firm	Purchase of products, sale of operating	Regional agricultural trading firm	Purchase of products, sale of operating	Involvement in the dissemination of measures

		material & machines		material & machines	
Other actors of minor interest for insect-friendly farming systems	Other administrative organisations	Reginal decision-making, authorization, management, etc.	Other administrative organisations	Reginal decision-making, authorization, management, etc.	Informed about project progress
	Local residents	Recreational activities, owner of home gardens, etc.	Local residents	Recreational activities, owner of home gardens, etc.	Informed about project progress

The actors' roles in the landscapes do not differ much in both lab regions. On basis of these roles we derived an adequate participatory strategy for the co-design process. Farmers, other land managers, and the biogas plant operator should be involved actively from the beginning in all phases of the process. In contrast, advisory service and business actors can be better involved in the later phases such as dissemination of measures and setting-up policy recommendations. Less important actors only need to be informed about the project progress.

Results of RQ2:

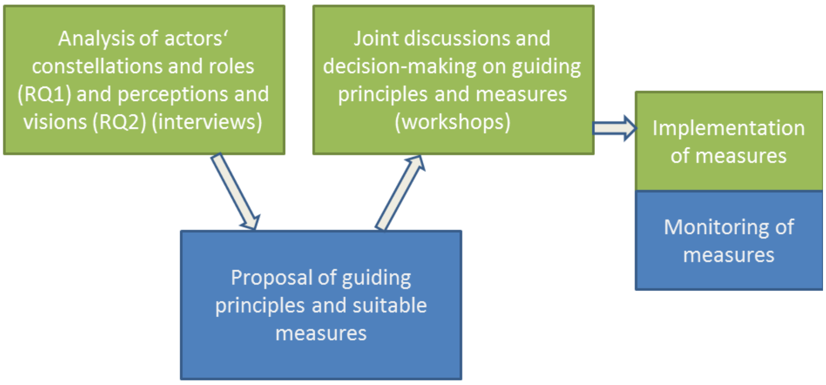
Interviewees differ, sometimes substantially, in their perceptions about a decrease in insects. For some farmers, the topic is more relevant, for others it has not played an important role yet. Many farmers did not perceive a decrease in insect biodiversity on their farms and in their regions. They often stated that they lack knowledge about insect biodiversity to be able to assess the issue. However, all of them were aware of the problem because of the high media presence of the topic in the last two years. A few farmers mentioned indirect indicators that they related to decreasing numbers of insects, for example less swallows nesting on their farmhouses. Some of the interviewees doubted that the problem even exists. Generally, farmers do not want to be blamed for the decrease of insects and be accused for being the sole culprits in the debate about reasons for the decline of insect biodiversity.

"To attribute the death of insects to the impact of agriculture, I believe, one should not do that and it is also incorrect. Rather, one should also look at the other aspects: Traffic, light, etc. What does it mean, more insects? If only someone would determine how many flies and how many mosquitos are killed on the streets, and how many used to be on the windshield—those are quite daring speculations. One should also look at the weather and … and … so much plays a role in this." (Q1)

Most interviewees advocate that the issue should be treated in a holistic manner, where multiple causes, such as light pollution, are considered as well. Some farmers feel that the image of agriculture has been tarnished by insect biodiversity discourses.

"The image of agriculture ultimately is not all that pretty. If we only look at the story of glyphosate that has been going through the media. I personally would be the first advocate to say, we don't need glyphosate … If the general public wants that, then it must obviously … be supported by everyone." (Q2)

Ecosystem services provided by insects in agricultural landscape, such as pollination and pest control play minor role for the interviewed farmers. Very few farmers mentioned the role that insects play for their regions. As it is difficult for the farmers to observe the direct correlation between the occurrence of beneficial insects and aspects such as their yield, monitoring results from the project are a reason for some of them to join the project.



In regards to actors' motivations, most farmers are open-minded, and are willing to participate in the landscape labs. They are aware of the need to contribute in general to insect biodiversity. They feel that performing insect-friendly farming will be required by the agri-environmental funding schemes in near the future. Participating in the project is also frequently considered as an opportunity to improve society's image of agriculture. However, some other farmers are more sceptical. Scepticism was stated in various forms. Many farmers mentioned that if alternative crops are grown as a measure to increase insect biodiversity (e.g., flowering energy crops), there has to be a demand and a value chain utilizing the produced crops. A lack of experience with alternative crops was stated as another obstacle for the implementation. A few farmers also reported on larger contexts, for example being held responsible for the insect decrease by the general public while consumers are not willing to pay more for food that is produced in an environmentally friendly way.

Some farmers already apply farming measures that support insects by providing nutrition and reproduction and hibernating/wintering habitats. They use flowering field margins or stripes, fallow periods, intercrop cultivation and others. Most of these measures are acknowledged as CAP greening schemes. At the same time, farmers often are not aware that these measures can be considered as insect-friendly. Some farmers also adapt their routines, for example by spraying pesticides at night when there are no bees present, on windless days, or in a point application.

The analysis of farmers' perceptions and visions is an important preparing step for the further co-design process of insect-friendly farming systems, which includes also the implementation and monitoring. The main steps of this process are illustrated in figure 2.

Figure 2: The integration of the both actors' analysis into the co-design process of the FInAL project. Boxes in green are steps with a close involvement of actors (mainly farmers) and boxes in blue are steps which are mainly performed by the scientists.

The farmers stated a broad range of individual requirements for the co-design of insect-friendly farming systems. Although farmers ask for proposals of suitable measures by agroecologists and agronomists, they want be actively involved in discussion and decision processes regarding the development and implementation of measures. Further requirements mentioned were stated regarding agricultural measures on the field and the surrounding landscape infrastructure (e.g. hedges or margins on water bodies). Concerning the agricultural measures on the field, interviewees had different views. Some preferred large-scale on-field measures (e.g. intercropping), because they require fewer working steps, whereas others preferred measures that focus on small and marginal areas (e.g. field margins). Most farmers prefer to conduct such measures on less productive plots. Generally, it is important to farmers that they can use the machinery they already possess. One farmer proposed to design a joint long-term rotation plan which involves different farm plots. The majority of the other farmers stated that they would support the idea. The opportunities that emerge from this collaborative approach are discussed in the next section. Preferences regarding the type of insects being fostered, for example a focus on rare varieties, biomass or beneficial insects, were expressed only occasionally. When the farmers referred to this aspect, their main concern was that the measures did not foster pests and harmful insects Promoting beneficial insects groups, such as pollinators and insect predators or parasites of pest insects was considered as a welcome effect but not an absolute necessity. Many farmers stated that they have only limited knowledge about insect biodiversity. Their knowledge is focussed on crop harmful insect species. Therefore, farmers wish to get in knowledge exchange with the scientists.

Discussion and Conclusion

Our interview results in form of actors' perceptions and visions can be contextualized with the broader public debate on insect biodiversity loss. The considerable interest of the general public and politics is reflected in the wide media coverage, an increasing number of scientific articles, petitions and political decisions. In the Federal State Bavaria, the public referendum 'Save the bees' for protecting biodiversity and natures' beauty was initiated by the BUND, a German nature conservationist organisation[107]. Due to the success of the referendum, the nature conservation law in Bavaria was amended in July 2019.[108] A reaction to the amendment proposal was that Bavarian farmers preventively cut their fruit trees to avoid that meadow orchards with fruit trees would be protected by the new law.[109] In the Federal State Brandenburg, the petition 'Save species diversity – save the future' has been started by the BUND and NABU in April 2019. The launch of the alternative petition for protecting insects ('Protect insects – preserve cultural landscapes') in the same Federal State and at the same time indicates that farmers and their organisations have a different point of view than nature conservation organisations. [110] They advocate that the insect topic should be treated in a holistic manner, where multiple causes are considered and a diversity of possible interventions is discussed. In general, many farmers feel pressured and some of them even negate any responsibility. In a statement, the managing director of a farmer association of the state Brandenburg and an initiator of the petition 'protect insects – preserve cultural landscapes' said: "*It is a fact that the living conditions for insects have*

[107] https://www.bund-naturschutz.de/aktionen/volksbegehren-artenvielfalt.html
[108] https://www.verkuendung-bayern.de/gvbl/2019-405/
[109] https://www.sueddeutsche.de/bayern/volksbegehren-artenvielfalt-biotop-baumfaellen-1.4445780
[110] http://initiativebienensummen.de/#

not worsened by agriculture in the past 25 years."[111] More drastically, he added: „*The insect lie is the biggest lie since the mad cow disease.*"[1] Our research project is not about finding culprits, it is about using the potential of agriculture and to find solutions together. Including the co-design approach actively involves farmers and aims at finding solutions that are viable and implementable by the practitioners. In our opinion, this is the way to go if the developed measures are to be accepted, disseminated to other agricultural landscapes, and to finally address the decrease of insects systemically.

Regarding the relevance for farmers and their motivation to participate we assume that the topic insect-friendly farming is mainly induced by science, decision-makers, media, and the public. Without the initiative through the FInAL project, this issue would not have been brought up by the interviewed farmers themselves. At the same time, farmers recognize the chance of getting involved in the project. The perceived benefit lays in the active contribution of developing future and practice-friendly agri-environmental funding schemes. Farmers perceive the public demand for a sustainable transformation of the agriculture system. Therefore, they want to be an active part of this transformation instead of only being an adopter of top-down decisions.

The farmers' proposal of designing collaboratively on the landscape level (including farm plots and the surrounding green infrastructure) provides opportunities for agroecology, social science, and agricultural practice at the same time. Some studies show that biodiversity conservation has to be considered on a landscape level and that landscapes consisting of diverse structural elements are beneficial for insects (Tscharntke et al. 2002; Steingröver, Geertsema, and van Wingerden 2010). In agricultural landscapes, cultivated plants such as oilseed rape (*Brassica napus*) or leguminous plants (*Leguminosae*) can also be a food source to insects but field margins usually exhibit a higher abundance of insect species than the centres (Stanley, Stout, and Clough 2013). Thus, it is necessary that close to the production area, within reach of the insects, there are non-crop areas which are suitable as insect habitats (Zhang et al. 2007). Fostering insects on a landscape level requires cooperation among the farmers that farm the respective land. The fact that the impetus for cooperation in one of the landscapes labs comes from a farmer and other farmers were open to this idea is a good basis for landscape level management. However, time will tell whether different interests and ideas of farmers can actually be harmonized and merged into a joint implementation of insect friendly measures. For social science, experimenting joint actions based on volunteers generates insights into how collaborative actions can be initiated, established and sustained. Additionally, it provides the opportunity to identify factors of success or failure and to build boundary concepts (Steingröver, Geertsema, and van Wingerden 2010). The benefits for the agriculture practice is in experimenting with joint actions, social learning, building up a farmers networks, and promoting social capital (Campellone et al. 2018; Steingröver, Geertsema, and van Wingerden 2010; Reed 2008).

As an outlook, the actors' roles, perceptions, and visions are an important basis for the further steps of our co-design process, especially in the development of measures at the landscape level. The outcome of the whole project is embedded in the broader challenge to contribute to the initiation of a system change that encourages a rethinking of current agricultural system and supports establishing an innovation niche. The approach of the FInAL project is future-oriented and integrative by including the landscape scale and their diversity of actors. Applying this approach, we contribute to the IFSA theme 6 'Landscape integration of farming'.

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WHAT LEARNING ARRANGEMENTS TO ACCOMPANY INNOVATING AGROECOLOGICAL MANAGEMENT OF LANDSCAPE RESOURCES ACROSS SCALES? LESSONS FROM THREE CASE STUDIES IN WESTERN FRANCE.

Claudine Thenail[a], Pierline Tournant[a] & Guillaume Pain[b]

a - INRA - UMR BAGAP - 65, rue de Saint-Brieuc - 35000 Rennes, France
b- ESA - UMR BAGAP - 55, rue Rabelais - 49000 Angers, France

Abstract

In the last decades, landscape changes in north-western France have been marked by a significant development of large livestock-cropping farms and of urbanized poles, but also of alternative agricultural systems (e.g., organic farming) and initiatives for regenerating cultural landscapes (e.g., bocage landscapes). In this context, developing research studies in landscape ecology /agronomy /management, in partnership with local actors (from farmers to local authorities), to foster sustainable practices of management of landscape resources, led us to point three main difficulties. They are related to: 1) the need for local actors to deal with uncertainties in the relationships between landscapes, management practices and ecological functions, 2) the mutual relative ignorance of farmers and land-use planners about their respective contribution to the landscape dynamic, 3) the gaps between agricultural and land-use planning schemes, and between these policy schemes and the local initiatives, in terms of involved actors, scales, objectives and processes. We present lessons learnt from three case studies, from field to regional scales, in which we are dealing with these difficulties by designing and testing learning arrangements with local actors. In the first case, with a group of farmers innovating in bocage agroforestry, we extend an agronomic diagnosis approach by integrating indicators of ecological functions, factors at play (landscape and practices) and farmers' management resources. In the second case, we propose realistic simulations of the contribution of farming production activities to landscape dynamics, as a support tool for land-use planning. In the third case, to support groups of actors in the design, the implementation and the ownership of green infrastructures, we propose a process in successive stages and tool kits for organizing local experiences.

Introduction

As recalled by Liquete *et al* (2015), maintaining and developing Green Infrastructures (GI) has been put forward by the European Union as a priority issue, GI being defined as a "strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services". In this perspective, GI have become shared features in several European policies dealing with *e.g.*, agriculture, biodiversity conservation, or land and resource planning (Liquete *et al.*, 2015). Still, difficulties in aligning these sectorial policies have been pointed (Hodge *et al.*, 2015; Xu *et al.*, 2019). Besides, Green Infrastructures are shared features for numerous and diverse stakeholders that have however different perspectives on GI, different managerial responsibilities or production objectives, at different scales, on different territories (*i.e.*, on different management, project and/or living areas). In fact the variety of stakeholders involved in such GI-schemes implementation processes remains quite low, while the beneficial role of public participation in such experiences has been shown (Xu *et al.*, 2019). Both the complex relative influences between actors on land-use decisions and the lack of knowledge of each other, are key issues that should be addressed to foster more participative and efficient GI design processes (Hauck *et al.*, 2016). In this perspective, stakeholders' involvement into social learning about GI underlying processes (*e.g.*, ecological processes or land-use decision making), and stakeholders' involvement into GI design and management projects may reinforce each other (Opdam *et al.*, 2016). Farmers may be envisaged as key stakeholders in such approaches considering their important roles in landscape management both as producers, land owners and citizens (Primdahl *et al.*, 2013).

In this paper we report from three case studies about the way we contributed to learning tools and approaches with stakeholders for GI sustainable design and management, with a specific attention to farmers' roles. These three case studies have been taking place in landscape-project territories situated on the Armorican Massif of North-Western France (Bretagne and Pays-de-Loire Regions). The area of the Armorican Massif is characterized by a bedrock of much eroded granite and diverse metamorphic rocks, a gently rolling terrain and an oceanic climate. Crop - livestock systems are the most common farming systems. Bocage landscape (*i.e.*, with hedgerows networks) is the main cultural landscape of the area. These studies range from farm to municipality then county scales, and from participatory approaches with mainly farmers and advisers to approaches with multiple stakeholders (*i.e.*, with land-planners, farmers and advisers, then also with *e.g.*, education actors and citizens).

After a presentation of the context, the starting points and content for each case study, we will discuss the lessons learned as regards the difficulties and opportunities outlined above and during the experiences. Hereafter, the phrases in italics correspond to the notes we have taken during workshops; they illustrate actors' feedbacks. The phrases that are both in italics and between quotation marks correspond to our translation of the actors' writing.

1. Accompanying farmers' innovations in bocage agroforestry from a principle of diagnosis-observatory in their farm and landscape context (case study nr1)

Agrarian systems combining trees with crops and grassland used to be common across European countries and more specifically, as in the French Bretagne Region, took the form of hedgerows alongside fields. In this region, the greatest development of what we would designate today as an agroforestry system fully integrated in both farming production and the local-regional economy (*e.g.*, tenure boundaries, main source of fuel and timber wood), was reached in the nineteenth Century. In the twentieth Century, a widespread removal of hedgerows occurred with land consolidation programs accompanying the productivity-based development of agriculture. The previous integrated agroforestry system turned into a variety of farmers' individual paths, according to their values but also to their evolving resources (human resources, *e.g.*, knowledge and workforce; material resources, *e.g.*, equipment and products; natural resources, *e.g.*, land). In the same period, scientists and environmental associations raised people awareness about the environmental issues associated to hedgerows and hedgerows-network landscapes (*i.e.*, bocage landscapes). More broadly, such awareness led to further incorporating environmental issues in both agricultural and landscape planning policies, with for instance hedgerows considered as green infrastructures eligible for cross compliance in the first CAP Pillar, or regional hedgerows-planting schemes. Maybe because bocage landscapes were then rather envisaged as remnants of totally vanished farming systems, and hedgerows primarily considered as environmental infrastructures, such schemes marginally involved farmers as managers and potential designers of hedgerows. In this context, a group of farmers and technicians founded an association[112] with the willingness of *"exchanging, educating and organizing so that the bocage culture remains part of the agricultural profession, in connection with the territories, which landscapes they [the farmers] contribute to shape"*. The association states working for *"the maintenance and renewing of a quality bocage linked to farming activity"*.

In the frame of a European project on agroforestry then a national research-development project, we[113] have developed research works in partnership with the farmers' association. The main issue addressed by the farmers and their advisers was *how to assess and monitor (including by*

[112] Terres & Bocage Association founded in 2008: http://terresetbocages.org/

[113] UMR BAGAP and UMR SAS in Rennes

themselves) their novel practices of design and management of hedgerows from a multifunctional perspective and as a baseline for further developments. In a first experience, we set up a study to assess the current differences in terms of environmental and agricultural functions between herbaceous field margins, young 15-20 years-old hedgerows (designed by the association) and old 100-200 years-old hedgerows in their farm and landscape context. We could assess that young hedgerows were of intermediate status between herbaceous field margins and old hedgerows in terms of biodiversity and carbon storage. Young hedgerows started to produce biomass for firewood and mulch, and to fulfill functions expected by farmers such as protecting and enclosing cattle in pastures, regulating soil erosion, or for landscape scenery[114]. If this first study allowed us to draw up a first state of play, it could not fully answer to farmers' main questions about assessing their practices, as the study focused on the functional implications of the presence, structure and age of the hedgerows at one point in time.

The works of this first stage were organized through introductive then feedback workshops with farmers and advisers, and the definition and implementation of on-farm observations, measurements and interviews. The feedback workshop of this first stage of work allowed us to have a collective discussion about the results and then, to further identify *farmers' questions about how to direct their practices to develop these multiple functions of hedgerows*. *For instance, farmers asked about how to favor biodiversity by their hedgerows design and their management practices (biodiversity for natural regulation but also birds or huntable species), how to assess and monitor their use of the "co-products" from hedgerows as organic fertilizer in fields, or how to assess if and how much fallen leaves contribute to soil organic matter in field.* It appears that such questions fit well into an agronomic diagnosis approach, which is well known by farmers. A diagnosis approach generally aims at identifying a problem of importance (*e.g.*, of decrease in yield) and the levers of action that could be mobilized to "solve the problem". The interest of such an approach is that it focuses on causal relationships between farmers' resources, practices and the phenomenon of interest, and aims at providing farmers with tools to make their own assessment (*e.g.*, indicators from observations). In our particular situation, such an approach required to be adapted, because i) the interest of farmers is not solely on fields but both on fields and hedgerows alongside, ii) the phenomena of interest are environmental and agricultural functions of diverse nature, iii) the landscape context is part of the drivers of environmental and agricultural functions, and iv) environmental and agricultural functions as well as farmers' practices, farmers' resources and the surrounding landscape are fundamentally evolving under different dynamics.

In this perspective, the ongoing work aims at designing and testing with farmers a diagnosis - observatory of the environmental and agricultural functions of contrasted fields and hedgerows alongside, as a learning arrangement to support farmers in further developments. The aim is first to describe the phenomenon of interest, *i.e.*, a process underlying environmental functions (*e.g.*, carbon input for carbon storage and organic matter availability, or type of flora biodiversity for complementary resources for pollen-gathering insects). Second, we constitute a step-by-step root causes analysis with farmers up to their practices (*e.g.*, carbon inputs to the soil under a hedgerow may come from plant residues because of grass crushing and/or herbicide spraying, but also from sediments due to soil erosion from upslope fields). Third, we go further in the root causes analysis up to their farm and landscape/territorial resources: such resources are at play in farmers' decisions and practices and may finally influence the environmental processes (*e.g.*, landscape diversity or mutual-aid networks may be such resources).

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[114]https://www.agforward.eu/index.php/en/bocage-agroforestry-in-brittany-france.html

2. Simulating the farmers' contributions to landscape mosaics and corridors at municipality scales from within-farms decision-making (case study nr2)

The "Green and Blue Corridors" French Policy (GBC scheme) has been stated in the frame of the National Strategy for Biodiversity, and organized at the regional level through the "Regional Ecological Consistency Schemes". The core objective, relying on landscape ecological principles, is to define and maintain ecological networks favorable to the movements and development of spontaneous flora and fauna, including both remarkable and ordinary areas. Within this framework, biodiversity issues shall be stronger integrated into account in local land-planning schemes. In Pays-de-Loire Region, hedgerow networks with associated grassland and ponds are identified as the "bocage network". In the frame of a research project dealing with farming contribution to ecological networks in periurban areas, we followed up the processes and debates of several developing land-planning schemes. At these local scales, bocage ecological continuities largely depend on the specificities and spatial arrangement of farming activities. Yet, in local debates and reports about the implementation of GBC schemes into land-planning schemes, farming activities were often mentioned in quite general or caricatural manner: the diverse farms and diverse ways of farming were not envisaged as drivers of landscape patterning diversity, hence not as potential levers of action. Moreover, in such regions of the Armorican Massif the fragmentation of farm territories (*i.e.*, parceling and scattering of farmland) and the rather smooth topography make it quite difficult to "read" directly the contribution of farms to local landscapes.

This starting point led us in this project to explore means to represent the contribution of farmers to landscapes due to farms diversity and within-farms decision-making[115]. One key aspect was to find a balance between realism and stylization of the landscape simulation so that scenarios of farming and landscape changes would be feasible and remain relevant in the territorial context. To perform the simulation, we chose one municipality (of about 60 Km^2) which was part of a larger territory under a process of setting up a territorial coherence program. Our objective was to assess from simulation the contribution of the diversity of farms to grassland ecological continuities at this municipality level. We identified and characterized different types of farming systems from farmers' interviews at the scale of the larger territory encompassing the municipality. Four types (to remain simple) of crop-livestock farming systems were identified, which mainly differed by their cattle production orientation and their rate of grassland and fodder crops *versus* annual crops for sell, in their overall crop acreage. The agricultural field pattern of the whole municipality was reconstituted from the Land Parcel Identification System (LPIS) and from aerial photography: 64 farms were identified, which fragmented territories stretched largely over the municipality area. We performed several scenarios, with allocating different combinations of farm types to the 64 farm territories. Then in each farm, crops and grassland (both temporary and permanent grassland) were allocated according to the crop acreage of the farm type, and according to the archetypes of farmers' decision rules collected during the interviews (*e.g.*, according to constraints of distance to the farmstead, of field surface, or to requirements in terms of grassland staying duration). In these landscape simulations, built-up areas, roads, rivers and very constraining fields of semi-natural grassland (*e.g.*, on very small, sloppy or wet fields, eventually with bush encroachment) were out of the simulation process and remain as in the initial observation. For each simulated landscape, the ecological continuities formed by the temporary and permanent grassland were measured with a simple indicator, namely the size of the largest patch of grassland. The results showed that the diversity of farm types within the municipality area significantly influences both the rate in surface and the spatial arrangements of the managed grassland. Such results may also depend on the contributions of the farms in area to the municipality territory, and the way they stretch over the boundaries of

[115] https://www6.inra.fr/programme-diva/DIVA-3/Les-projets-DIVA-3-retenus/TRAMIX

the municipality, as *e.g.*, the distance of the fields to the farmstead is a criterion in farmers' decision rules of land-use allocation. Finally, according to the simulations, the spatial arrangement of the managed grassland as regard other green infrastructures such as the small semi-natural grassland fields, may foster the emergence of larger ecological continuities. Hence, the maintenance of all these green infrastructures depending on very diverse stakeholders is at stake.

The principles and results of this simulation test have been presented as one case study in the introduction of a workshop of debate on the theme "Farming practices and biodiversity preservation in the implementation of spatial planning policies"[116]. The participants were (beside teachers-researchers and students), actors from chambers of agriculture, local authorities, environmental associations and engineering offices. We report now some issues underlined by the participants from the listening of the simulation case study. *The participants first emphasized that GBC schemes indeed call out of a logic of zoning opposing (roughly said) areas of nature with biodiversity experts versus areas of agriculture with farmers more and more "disconnected from their environment". In fact, agricultural areas should be seen as multifunctional areas, and so called "natural areas" should not exclude farmers. Nevertheless, these principles of GI design and management face several operational challenges, mainly linked to the territorial scales (municipality, inter-municipalities) at which GI should be implemented to be functional. Most often agriculture-biodiversity projects have been developed at small site scales with voluntary farmers; and even at these scales, an ecological follow-up is not always performed. To deal with GI issues at broader "territorial" scales, it is necessary to both enhance the capacities for action of the different actors at their respective level of work, and their capacities for collective commitments in a collaborative frame for reworking landscape mosaics. Yet this is clearly at these scales that farming dynamics are difficult to figure out and biodiversity difficult to monitor. To sum up, at these territorial scales it is difficult to conceive what is played out and what is at stake: means should indeed be developed to support actors of local territories to appropriate the subject and relay the issues.*

3. Developing a GI design approach with multiple stakeholders at county scales (case study nr3).

In the perspective of implementing the GBC scheme in Bretagne Region, *local stakeholders raised the issue that no methodology was provided to implement such schemes at sub-regional scales. Yet, Green Infrastructures are supposed to be consistently designed from regional to local scales, across the administrative boundaries, and they concretely concern numerous diverse people.* From this starting point, a project has been initiated in close partnership between research and open environmental education[117] (referred to below as the project team). The purpose of the project was the participatory design from multi-actors experiences in pilot areas, of a methodology for accompanying these actors from raising awareness about biodiversity and Green Infrastructures, to operational implementations of GBC schemes[118]. The project team proposed experiences and tools to be tested in pilot territories to local technical committees composed by voluntary participants (of *e.g.*, chambers of agriculture, farmers' associations, tasks officers of local authorities, environmental associations, hunting federations, water catchment syndicates), and collect feedbacks during these experiences. From those feedbacks, the project team proposed novel experiences and tools or a deepening of what has been proposed. The project was therefore organized in an iterative process of learning from the experiences.

The experiences that have been proposed during the project were for instance: i) on-field experience of carabid-beetles' observations to discover ecological functions and movements across the landscape, ii) a workshop for testing different methods for identifying and mapping GI-

[116] http://www.groupe-esa.com/les-rencontres-esa-inra/
[117] URCPIE Bretagne: Regional Union of Permanent Center for Environmental Initiatives
[118] https://tvbchemins.com/

networks, or iii) training sessions about "how to tackle Green Infrastructures issues with different publics", or "how to implement GBC-schemes on territories". Some feedbacks from these experiences are illustrated hereafter. *Recurrent questions were in fact about how to identify ecological continuities (with what indicators), how to mobilize the actors of the territories and how to build up an action plan. The participants to the local committees expressed that it was difficult for them to grasp such notions of ecological continuities. During on-field experiences bringing together farmers and other actors of the local committees, farmers were surprised to discover so many carabid beetles in the pitfall traps on their land, especially the differences between the center of the fields and the field margins; from this experience, they better understood this notion of movement of species across the landscape. The participants of the workshop for testing methods had difficulties to relate the proposed maps to the reality of the field from their viewpoint in their working context; also such maps should be realistic enough but without entering into too fine spatial details.*

The succession of experiences allowed us to identify three major stages for a GBC project approach, namely a first general diagnosis stage (for identifying the main issues of the local territory), then a specific technical diagnosis stage (for identifying, mapping and choosing the GI) and finally an operational stage for the definition and implementation of the action plan. Partners of open environment education particularly emphasized that guiding the actors shall be envisaged as a process that goes through all stages of the GBC project approach, with ongoing development of competencies (actors from open environmental education and other novel actors) and tools. The project team has been developing a tool kit in this purpose; it contains for instance educational tools, practical guides or documents depicting experiences. For instance, we have been participating to the elaboration of a practical guide presenting methods for identifying and mapping Green Infrastructures: we particularly emphasize the assets and limitations of the different methods according to the context.

4. Discussion

In this paper, we report the way we contributed to learning arrangements for GI sustainable design and management in the frame of projects in partnership with different stakeholders. We had a special attention about the role of farmers as key managers of landscape resources since they largely determine the way landscape elements and mosaics may evolve in their structures and functions hence associated ecosystem services. In this section, we discuss about the complementarities between the three case studies. Prior to that, we want to point out that difficulties in GI design and management approaches were encountered as in former studies (see introductive section), such as gaps between policy schemes and local initiatives, between stakeholders interests, also socio-technical locking experienced by farmers (Pinto-Correia and Azeda, 2017). In terms of research approaches, sometimes misunderstandings arose because researchers were rather expected as experts than as active contributors to co-learning approaches.

Through the three case studies, our contribution to support methods for the design and management of Green Infrastructures may be structured as first synthesized by Liu *et al* (2002) according to three proposed shifts in natural resource management (Liu and Taylor, 2002).

The first proposed shift is from single-scale to multi-scale management (Liu and Taylor, 2002). The proposal we made in this set of studies was to bring explicitly to stakeholders different scale perspectives. In the first case, as the design and management of elementary GI was at stake, we proposed to involve farmers into a scaling down perspective. For this, we helped them to take into account in their observations the nearby landscape and territorial environment in terms of drivers of ecological functions and in terms of resources or constraints to change or maintain their practices. In the second case, the simulation process was proposed to stakeholders for a scaling up experience: the issue was to be able to represent with sufficient realism and simplicity, the emerging properties of the landscape mosaics at a municipality level starting from decision processes within farms. In the third case, scaling-up and -down experiences were proposed to stakeholders with *e.g.*, on-field observations and tests of mapping methods, to help them understanding how ecological processes but also how drivers of these processes were developing from one scale to another.

The second proposed shift is from within-boundary to cross-boundary management (Liu and Taylor, 2002). This is an issue as the spatial-scale mismatches between ecological and managerial processes hamper the understanding and assessment of the way they interact (Pelosi *et al*, 2010). Such mismatches were multiple in our context, since several managerial areas partially overlapped with each other (*e.g.*, farm territories with administrative territories and other project areas) and with ecological patterns. In the first study case, the farmers of the association themselves proposed a first "cross-boundary step". Considering the hedgerows as part of their farming systems, they asked for better understanding the ecological interactions between the fields and hedgerows alongside, as driven by their management practices. This is why we proposed a diagnosis setting, which firstly aimed at accounting explicitly for these interactions. A second "cross-boundary step" for the farmers was about taking into account the resources and constraints of their surrounding other territories. In the second case study, the simulation procedure emphasized that the fragmentation and stretching of farm territories beyond the municipality boundaries played a role in landscape patterning within the municipality, which would not have been fully understood from *e.g.* the intrinsic characteristics of the fields. In the third case study, the experiences with the various stakeholders (including farmers) were organized to make them perceive and understand these mismatches between ecological and managerial processes, so that they could consider them in GI design and management.

The third proposed shift is from static to adaptive management (Liu and Taylor, 2002). The principle is that static objective-driven management cannot be operational when the system to be managed, here the landscapes with these GI components, is highly complex and changing. Shifting to adaptive management supposes to be able to reformulate the objectives and adapt the practices and mobilized resources according to the changes of the system. Such a management approach supposes to place a great emphasis on the on-going acquisition of knowledge by actors to deal with uncertainties, variability in time and great changes in the system. This notion of adaptability may be questioned, not only as regard the management but also the design of GI (as illustrated hereafter). In all study cases, we put the emphasis on developing tools and methods to support stakeholders in such capacities of on-going knowledge acquisition. In the first study case, the farmers' questioning about the directions they were undertaking with their innovating practices, encouraged us to formulate with them a diagnosis-observatory arrangement. In this first case, the question of adaptability was also addressed as regards the design of GI: the type of trees or the way they were planted (*e.g.*, in one or several rows) were discussed in the association as regards their adaptability to *e.g.*, climate changes or also long run changes of production needs. In the second study case, the simulations of the consequences on landscape patterns of the different combinations of farm types were mimicking, to some extent, the consequences of possible changes of the local agriculture. In the third case, the project was based upon the principle of an adaptive learning arrangement between stakeholders to formulate a GI design approach that could be itself adapted in time.

5. Conclusion

The experiences from the three case studies confirm the interest of "entering" with stakeholders into the complex causal relationships between their activities, the dynamics of landscapes and multiple associated functions. These co-learning principles differ from some assessments principles where these causal relationships largely remain in a black box for the stakeholders. Participatory observatories and simulations/scenarios of such causality chains may foster stakeholders' innovations for more sustainable GI design and management across territories (Spanòa *et al.*, 2017; Schmidt and Hauck, 2018). In this perspective, information, education and cooperation/networking are important instruments to support farmers' landscape management (Primdahl *et al.*, 2013). Considering this key position of farmers among stakeholders, we underline the interest of inviting them in a scaling- up and -down learning approach as regards landscape issues, *i.e.*, considering the effects of their field-scale practices on the landscape structure and functions, and the effects of the landscape environment on field-scale practices and functions.

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REWILDING THE RISK SOCIETY ON SMALL FARMS

Dominic Duckett [a], Hilde Bjørkhaug [b]

[a] Social, Economic and Geographical Sciences Group; The James Hutton Institute Aberdeen, UK
[b] Ruralis; University Centre Dragvoll (NTNU) Trondheim, Norway

Abstract: Sustainable Development Goals around environmental goals to both mitigate anthropocentric climate change and promote biodiversity typically involve productivity tradeoffs for the agricultural sector as it is currently configured. Feeding the world's burgeoning population has been historically met with initiatives to significantly increase food production by extending agriculture at the expense of wilderness and has included the suppression of wild animals alongside an engineered reduction in biodiversity. Arguably this has been the global pattern over the millenia but, more than ever before, Food and Nutrition Security agendas are framed in terms of raising global farm production between 50-100% by 2050.

Farmers, who have traditionally seen wild nature as a risk to their livelihoods, have achieved increases by controlling wild predators and taming the wilderness. Radical rewilding supporters promote rebalancing traditional agricultural practices in favour of widespread restoration of wilderness areas and purposive reintroductions of wild species including the same predators that farmers have hitherto controlled. Rewilding, as a tool to promote environmnetal goals, tends to have decreased agricultural productivity even where some food production is encouraged; conversely, increasing farm productivity has not been generally approached through rewilding.

The SALSA project[119] has engaged with small-scale food system actors cultivating land and raising livestock accross Europe and Africa, often in remote or less favoured areas (LFA). Their farms are often considered prime sites for rewilding and afforestation initiatives, or are adjacent to spaces already subject to special deignation, for example National Parks and wildlife reserves. This is partly owing to what has been viewed as the marginal contribution of small scale agriculture to wider food systems.

SALSA stakeholders accross europe and africa, when interviewed about constraints to food production, complained about predatory and destructive wild animals. More food could be produced, many contended, through de-wilding rather than re-wilding particularly in relation to predator control for livestock. Even small farmers advocating rewilding recognised corresponding production constaints.

'The Risk Society' contextualises risks within modernity offerring a lens to explore what have been perennial risks for farmers, yet can be seen as products of advanced farming systems, modern institutional contexts, contemporary values, and neo-liberal political strucures. Our paper examines the self-reported experience of small farmers in dynamic landscapes and the rapidly evolving governance environment reshaping the small farming world.

[119] SALSA is a Horizon2020 project conducting research into small farms, small food businesses and sustainable food and nutrition security http://www.salsa.uevora.pt/en/

INTERACTIONS BETWEEN BEEKEEPING AND LIVESTOCK FARMING SYSTEMS IN AGROPASTORAL LANDSCAPES: A CASE STUDY IN THE SOUTHERN MASSIF CENTRAL, FRANCE

Gabriel Gonella[a], Estelle Leoni[a], Léo Mouillard-Lample[b], Claire Aubron[c], Marc Deconchat[a], Axel Decourtye[d], Cécile Barnaud[a]

[a] UMR Dynafor, INRAE Toulouse, France
[b] UR Abeilles et Environnement, INRAE Avignon, France
[c] UMR Selmet, Montpellier SupAgro, Montpellier, France
[d] ITSAP Institut de l'abeille, INRAE, Avignon, France

Abstract: From columns to "save the bees" to calls to "conciliate beekeeping and agriculture", agriculture is often pointed out as responsible for pollinators decline and the beekeeping sector difficulties. At the same time, agriculture, as a major factor of landscape constitution, is an unavoidable lever to solve these very issues, namely through the floral resources it shapes. However, knowledge about the impact of agropastoral farming systems on floral resources for beekeeping is still scarce. How do various livestock farming system contribute to the construction of floral resources in agropastoral landscapes? What are the consequences of this construction for various beekeeping-farming systems?

In order to answer these questions, we led an agrarian diagnostic in a middle mountain massif of southern France. We identified various livestock farming systems and beekeeping farming systems, and their respective impact on and dependence to floral resources. This led us to reveal livestock-beekeeping farming systems technical-economical interactions at various spatio-temporal scales:

cultivation practices (choose of cropped species, irrigation, fertilization, mowing) in the short term,

"open" landscapes maintenance in the medium term

land intensification and land abandonment in the long term

Beekeeping farming systems have adapted to changes in floral resources and to the global changing beekeeping conditions. They did so by adapting their uses of traditional floral resources or by shifting to new ones.

Accounting for floral resources and beekeeping farming systems dynamics is helpful to inform agropastoral landscapes management, in order to elicit beekeepers and farmers cohabitation.

THE HEARTLAND PROJECT: HEALTH, ENVIRONMENT, AGRICULTURE, RURAL DEVELOPMENT: TRAINING NETWORK FOR LAND MANAGEMENT

C. Grace[a], T. Boland[b], R. De Goede[c], E.R. Gibney[d], J. Gilliland[e], E. Hoffland[f], B. Lynch[g], R. Ripoll Bosch[h], O. Schmidt[i], R. Schulte[j], H., Sheridan[k] J. Kennedy[l]

[a] Devenish Nutrition
[b] University College Dublin
[c] Wageningen University and Research
[d] University College Dublin
[e] Devenish Nutrition
[f] Wageningen University and Research
[g] University College Dublin
[h] Wageningen University and Research
[i] University College Dublin
[j] Wageningen University and Research
[k] University College Dublin
[l] Devenish Nutrition

Abstract:

Ruminant livestock production is often criticised for its negative impacts on the environmental and human health. For example, it can be associated with land use change such as deforestation, methane emissions and associated climate change, NH_3 deposition and biodiversity loss. At the same time livestock protein is the main source of protein in most European Member States. However, it is increasingly recognised that ruminants convert biomass unsuitable for direct human consumption into valuable food, including essential proteins and micro-nutrients. In addition, while high input and intensively managed systems may have negative environmental consequences, less input dependent systems are recognised as central to the retention of culturally important landscapes, High Nature Value Farmland (HNV), biodiversity and associated regulating ecosystem service provision such as carbon sequestration, nutrient and water cycling, pollination and pest control.

An on-going Marie Skłodowska Curie project called HeartLand (Health, Environment, Agriculture and Rural development: Training on LAND management) which is taking place in Ireland and the Netherlands is attempting to understand the challenges and opportunities arising from livestock farming for human and environmental health. This European Industrial Doctorate (EID) programme will connect one of the most notable industry initiatives (at the Lands at Dowth (Ireland) of Devenish Nutrition) to the cutting-edge scientific knowledge on sustainable and healthy food production (being generated at Wageningen University and Research, University College Dublin and University of Gloucestershire). The impact of this EID programme will be maximised by working closely alongside experts in communication in the European Food Information Council (EUFIC) and the Bord Bia (Irish Food Board).

Introduction:

Livestock farming is increasingly in the spotlight of scientific literature, the popular media, and the public opinion because of its impacts on the environment and human health (Garnett et al., 2017). At the same time, global population is predicted to increase by between 70-100% (relative to 2005-2007 levels (FAO, 2009)) increasing the demand for healthy food production (Burney et al., 2010). Thus far, the livestock industry worldwide has largely responded defensively to this dual challenge, often questioning the validity of these concerns.

Indeed, ruminants can convert biomass unsuitable for direct human consumption (e.g. grass resources from land that is unsuitable for arable farming) into valuable food, including essential proteins and micronutrients for human consumption. Therefore, grazing systems are a vital indirect source of these essential nutrients for the world's growing population (Boland et al., 2013), which is predicted to increase to approximately 10 billion people by 2050 (Smith et al., 2013). Coupled with the necessary increase in quantity, food quality will also have to improve (Smith et al., 2013). Achieving the necessary increase in food production will be a challenge due to the combination of limited additional land availability, coupled with the on-going and historical depletion and degradation of natural resources (Smith et al., 2013). Meeting this challenge will require livestock production systems to become more environmentally, economically and socially sustainable and key to this is resource use efficiency (O'Brien et al., 2016).

Within temperate areas, improved agricultural grasslands are heavily dependent on perennial ryegrass (PRG) (*Lolium perenne* L.) (Grogan and Gilliland, 2011) with small quantities of legume species such as white clover (*Trifolium repens*) also included (Waghorn and Clark, 2004). In Ireland, PRG accounts for 95% of forage grass seed sales (DAFM, 2018). Perennial ryegrass swards can be highly productive, capable of producing 12-15 tonnes of DM ha^{-1} yr^{-1} in Ireland under appropriate management (O'Donovan et al., 2011) and are of a high nutritional value (Fulkerson et al., 2007). Maintenance of PRG swards however is dependent on the supply of large quantities of nitrogen (N) (Whitehead, 1995) and it quickly disappears when N becomes limiting (Sheridan et al., 2008). Nitrogen inputs represent a significant direct cost to farmers (CSO, 2017; Dillon et al., 2017) and also contribute to wider environmental problems such as water pollution, increased nitrous oxide emissions, NH_3 deposition and loss of biodiversity (Stark and Richards, 2008). The EU Nitrate Directive; Council Directive 91/676/EEC was introduced to address these environmental concerns through placing limitations on both the quantity and timing of N application allowed in Member States.

Most productive grassland research in temperate regions has focused on the use of PRG over the last number of decades. However, there has been an increasing interest in the role of multispecies swards comprised of grasses, legumes and forage herbs, for the development of more sustainable grazing systems in recent years. Multispecies swards grown under reduced N input conditions (relative to PRG monocultures) have also been shown to have positive effects on herbage quantity, quality, animal performance (Grace et al., 2018a; Grace et al. 2018b) and biodiversity. The increased biomass production compared to monoculture swards, is primarily due to complementarity between the different species included within these swards (Kirwan et al., 2007).

A Marie Skłodowska Curie European Industrial Doctorate project called HeartLand which started in October 2019 is addressing the contemporary industry challenge to develop livestock production systems that simultaneously enhance environmental sustainability. The role of multispecies swards will be examined in terms of sustainable livestock productivity, product quality, delivery of ecosystem services to society and efficient resource use. HeartLand is based at the Devenish Lands at Dowth which is within the Brú na Bóinne UNESCO World Heritage Site. Throughout its history this site has been maintained as a single large landholding and as such represents the evolution of farming over 6,000 years in a single holding.

Methods:

The project will consist of 5 PhD students who will collate data from two main experiments described below. From the experiments, analysis on soil, swards, animal performance and the social impact of the experiment will be examined as well as a data modelling exercise conducted as described below:

Experiments

There will be two main experiments conducted: a component (Exp. 1) and a systems research experiment (Exp. 2). The component research is in the form of experimental plots and will take place at the Devenish Lands at Dowth. The experiment will consist of a factorial arranged experiment with four sward types, two establishment methods (direct drill and a cultivation and sow method) and with/without slurry application. Swards types being examined are; a permanent pasture sward which was the old permanent pasture that existed in Dowth, a PRG only sward, the 6 species sward containing; two grasses (PRG and timothy (*Phleum pratense*), two legumes (white and red clover *(Trifolium repens and pratense))* and two herbs (ribwort plantain (*Plantago lanceolata*) and chicory (*Cichorium intybus))* and the 12 species sward containing cocksfoot *(Dactylis glomerata)*, greater birdsfoot trefoil (*Lotus pedunculatus*) sainfoin *(Onobrychis viciifolia)*, yarrow (*Achillea millefolium*), salad burnet (*Sanguisorba minor*) and sheep's parsley (*Petroselenium crispum*) in addition to the six species listed for the 6 species sward.

The systems research will be an experiment with same four sward types as the plot experiment at Dowth (permanent pasture, PRG only sward, a 6 species sward and a 12 species sward, replicated four times) which will be rotationally co-grazed by sheep and cattle stocked at 2 LU ha^{-1}.

Soil studies

Analyses will be done to profile the impacts of the plot experiments (above) on:
1) Delivery of the five soil functions i.e. production of food, feed and fibre, provision of habitats for both functional and intrinsic biodiversity, carbon sequestration, regulation and provision of clean water, and the provision and cycling of nutrients, will be carried out using the methods and indicators developed in the SQUARE and LANDMARK projects (Schulte et al., 2014). 2) The role of soil biota in enhancing the nutritional quality of sward herbage and the soil's ability to minimize losses to the environment. 3) the impacts of sward composition, establishment method and soil improvement on soils, nutrient losses to the environment and nutritional quality of the sward. This part of the project will focus on maximizing synergies between sward composition and soil functions. The aim is to design, implement and evaluate the effect of sward type on the provision of habitats for both functional and intrinsic biodiversity, carbon sequestration and regulation of water (through soil structure). The impact of the different sward compositions on soils will be monitored in terms of: 1) Earthworm densities, species and activities, and knock-on effects on soil structure including soil stability and drainage. The sward researcher and the soil researcher will work together to fully develop this part of the experiment. 2) The soil nematode community as indicators for soil ecosystem functioning 3) Functional biodiversity of the soil microbial community 4) Carbon stabilization (as an indicator for carbon sequestration) and 5) Micronutrient availability to the herbage.

Sward studies

This researcher will profile the impacts of the plot experiments (Exp. 1 and 2) on 1) sward: dry matter yield production, nutritional value, species establishment and persistence in the swards over time. A baseline botanical composition of the existing permanent pasture at Dowth will be undertaken. Botanical composition of the multispecies versus monoculture swards will be identified and changes in the botanical composition will be tracked over two growing seasons. The dry matter yield of the swards will be determined and the effects of establishment method, soil improvement and N fertiliser regime will be determined to investigate if transgressive over-yielding occurs. The effects of sward composition, establishment method, N fertiliser regime and soil improvement on earthworm abundance and diversity and water infiltration will also be investigated.

Model development

This reseacher will explore pathways for healthy farm management (economic, social and environmental sustainability), based on healthy soils, healthy swards and animals in the context of societal requirements for healthy people and a healthy planet. The researhcer will analyse and design options for farm management systems, integrating soil management, grassland management, animal management, labour management and financial management. The FarmDESIGN programme as per Groot et al., (2012) will be used to 1) describe, 2) explain, 3) evaluate, 4) design - solution spaces for healthy farm management based on results collected from both experiments.

Animal nutrition and Human Health studies

This researcher will examine the impact on animal growth performance, parasitic burden, enteric methane emissions, beef and lamb meat quality and nutrient content of grassland management system as influenced by sward composition and soil quality. This will generate meat nutrient profiles which will be modelled on their potential health impacts of consuming higher nutritive content beef and lamb, using dietary intake data provided by the European Food Safety Authority's Comprehensive Food Consumption Database on food consumption habits and patterns across the E.U. They will quantify the impact of sward and soil management system on animal performance, animal health and product quality. The researcher will model dietary intake of consumers consuming conventional beef and lamb compared to HeartLand beef and lamb.

Environmental Health studies

This researcher will explore how the creation of healthy farms that produce healthy food can potentially deliver and contribute to a healthy society and a healthy planet. They will elevate the findings at the research farm beyond the farm boundaries, and place them in the context of the societal requirements at a regional scale and they will apply the Functional Land Management (FLM) framework currently employed in the H2020 project LANDMARK (Schulte et al., 2015).

Discussion:

Through a series of interlinked experiments and collaborations with the various universities and industry groups this project aims to explore fully the development of more sustainable animal production systems, from soil to society. It brings together plant, soil, agricultural ecology and animal scientists as well as social scientists from leading universities (Wageningen University, University College Dublin and University of Gloucestershire) and industry involvement (Devenish Nutrition, Bord Bia and the European Food Information Council (EUFIC)). Collaboration involving industry and universities will ensure a good vehicle for enhancing knowledge transfer, intersectoral mobility and mutual understanding.

The HeartLand project will address the following challenges: it will unlock the potential of multispecies grasslands; aims to improve human health through improved soil health and establish production systems that contribute to both human health and agricultural sustainability. While in recent years there has been more research into more diverse swards, to date, there has been no comprehensive assessment of the role of diverse grasslands or multispecies grasslands in creating (potentially additional) economic advantage to farming systems. As well as this, there has not yet been an assessment into the full chain, from soil quality to herbage quality to the quality of the animal products produced. The question also remains to be answered if management aimed at healthy food production aligns with management aimed at sustainable food production. The challenges and unknowns of this project will be examined through the following research objectives: 1) To assess and integrate the relationships between grassland diversity and farm economics 2) To assess and integrate relationships between soil quality and meat quality through the full production chain 3) To provide integrated assessment and management systems that deliver healthy farms, healthy people and a healthy planet.

The HeartLand project aims to provide ruminant production systems that will to be impactful on the environment, economics and human health. It is well known that the agricultural sector has been challenged to increase agricultural productivity while simultaneously providing ecosystem services such as the provision of clean water, habitats for biodiversity, recycling of nutrients and mitigation against climate change (Schulte et al., 2014). The Heartland project will examine the effect swards have on water infiltration, earthworm abundance (and diversity) and through the Catchment Challenge workshops delivered as part of the project will examine how functional land management may be possible in Ireland.

The European Union has a long tradition of incentivisation, largely through payments under the Common Agricultural Policy, including payments for Less Favorable Areas and payments under various national Agri-Environment Schemes, which are aimed at providing a financial incentive to farm in a more environmentally manner. If improvements were made in the provision of the aforementioned ecosystem services in the grazing systems that are being investigated within this project, coupled with reduced N requirement, there may be scope to potentially incentivise farmers to adopt these management systems.

Within the project, the nutrient quality of the meat produced from these sward types will be investigated and nutrient density scores will be calculated, similar to work carried out by Smedman et al. (2010). Comparisons in nutrient density scores will be made across sward types. Nutrient density scores will be given to meat products taking into account their nutritive quality and the green house gas emissions per kg of product produced.

The HeartLand projects will impact on the careers of the PhD students involved and train them with comprehensive knowledge into sustainable food production. It will enhance the career prospects and employability of researchers and contribute to their development. It is increasingly clear that the resolution of complex environmental and human health problems requires interdisciplinary, intersectoral expertise and cooperation from academic and industry.

The findings and results of this project will be disseminated through scientific publications in peer-reviewed journals to target the scientific community, presented at conferences and at HeartLand seminars that will be held at The Devenish Lands at Dowth. A Heartland website has also been developed to disseminate the research to scientific and non-scientific audiences. Furthermore, HeartLand will use Twitter to provide regular updates on everyday activities from the project to engage with the farming community and other industry personnel.

The Heartland project offers a unique approach to the investigation of potential solutions to address many of the challenges currently facing ruminant production systems. Our future prosperity depends on increasing food production in harmony with nature while using the food we grow effectively for nutritious, varied and safe diets. The bold proposition underpinning HeartLand is that sustainability and health are inextricably linked, all the way “from soil to society”.

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ARE FARMERS WILLING TO PAY FOR REGIONAL FARMERS' NETWORKS? - IN SEARCH OF BUSINESS MODELS

Scholz S.[a], Bloch R. [a, b], Häring A.M.[a]

[a] Eberswalde University for Sustainable Development, Germany

[b] Leibniz Centre for Agricultural Landscape Research (ZALF), Institute of Land Use Systems, Germany

Summary

A new regional farmers' network approach, *The Cropping School*, was launched in Brandenburg, Germany. The main goal of the *Cropping School* is to empower farmers to identify cropping system problems and to improve their cropping systems in a facilitated peer-to-peer setting. Today farming is highly affected by climate change and market fluctuations. In order to be able to adapt to the changing conditions, regional problem solving approaches and specific innovation are required. Therefore, a high demand on regional farmer's research networks could be identified in Brandenburg, Germany. By calculating the current cost of such a farmer network, identifying the farmers' stated willingness to pay for this service via face to face interviews and by evaluating the federal state specific framework for advisory services, we developed a business model to continue the network after project funding. Results show that three different business models are possible for a farmer network in Brandenburg, Germany.

Introduction

Farmers' networks – a tool for developing individual methods for strengthening farm resilience.

European and German agricultural research policy increasingly focuses on networking projects. By October 2019, the European Innovation Partnership's *Agricultural Productivity and Sustainability* program (EIP-Agri) had launched 201 networking projects in Germany alone (BLE, 2019). Numerous other funded network projects have arisen from national strategies and programs, financing research and innovation propositions in cooperation with scientific institutions as well as with business, advisory and practical professionals (BLE, 2014).The motivating force behind this increase in networking and network approaches in agricultural research policy is threefold: a) to accelerate innovation, b) to increase farming productivity while using a minimum of resources, and c) to thereby strengthen farms' sustainability (BLE, 2019).

In agricultural practices knowledge, especially explicit and implicit knowledge as well as garnered experience plays a vital role (Lehmann 2005). According to Thomas, Hoffmann and Gerber (1999, cited by Lehmann 2005), this comprehensive claim on competence can only be met by integrating varying forms of knowledge transfer. Important elements are experience and practical learning on one's own farm as well as exchange with colleagues. Informal gatherings among colleagues create an open space; a casual atmosphere that can be shaped individually or collectively (Luley 1996). Group structures inspire exchange relationships, promoting innovative action (Luley 1996, Luley, et al. 2015). Hands-on experiments are one of the elemental learning strategies (Kummer et al. 2012), they are an effective instrument for making appropriate decisions (Scooby 2001), which introduce new methods and innovative activities to specific agricultural conditions (Bloch et al. 2016, Kummer, et al. 2012). Regular exchange opportunities between farmers can promote the development and practical application of individual solutions. A *Cropping School* is such a group approach by which an active farmers' network is supported by scientists and advisors (Scholz et al., 2018) in a facilitated peer-to-peer setting. A *Cropping School* enables farmers to identify problems and to take appropriate action, thereby improving their cropping systems. Typically, farmers discuss self-identified agricultural problems during regular meetings, which take place in turn on participating farms. Applying a farmer-to-farmer learning approach, the network helps to identify cropping problems and to develop practical solutions.

Consistency and long-term financing is one of the greatest challenges networks face. Reliable network structures are necessary to provide farmers continuing support for sustainable innovation processes.

This paper examines business models, which could be appropriate to ensure networks' continuity. Furthermore, this paper explores the cost of and the willingness of participants to pay for a *Cropping School*.

Background

Networks, cooperation and alliances

The terms *network, cooperation* and *alliance* are often used synonymously. Due to the term *network*'s abundant application, Kappelhoff speaks of (2000, cited by Bornhoff and Frenzer, 2006) a *compact term*, applicable to a wide range of definitions. The word's copious usage has given rise to countless compound terms such as *strategic network, organizational network, regional network* and *innovation networks* that circumscribe a network's function, thereby specifying the term's definition (Morschett 2003; Bornhoff and Frenzer 2006).

In this paper, *farmers' networks* are understood as a link between several legal and economically independent organisations which have been conceived for long-term continuity. Resources, knowledge and capabilities are donated and/or shared voluntarily among the participating members. The participants are rather loosely connected (i.e. there is no economic or legal links), yet there is an elemental, mutual dependency (i.e. the network would not exist without a mutual exchange of knowledge, or without a network coordinator).

Farmers' networks in, or in addition to, agricultural advisory services

All over the world farmers' networks approaches like *Farmer Field School*, *Farmer study circles* or *Farmer study groups*, *Farmer to Farmer Network*, *Innovative Farmers* or *Stable School* can be found. These networks differ widely in terms of network concepts structures. Common to all approaches is their objective to empower farmers to improve their businesses (Table 1).

Due to its federalist structure, Germany's advisory systems are highly diverse (Knierim, et al. 2017). In some federal states, like Brandenburg, advisory systems are dominated by private enterprise consultancies. Farmers' networks or group advisory formats are unknown. In other federal states, group advisory formats and farmers' networks are predominantly subject-specific farmer discussion groups offered by state-funded advisory organizations or farmers' associations. *Stable Schools* are piloted by research institutes in cooperation with advisory organisations. Selected examples of current farmers' networks or group advisory offers in Germany are shown in Table 1. By evaluating these examples, conclusions can be drawn for a long-term *Cropping School* business model in Brandenburg, Germany.

Table 1 Examples of farmers' networks and their business models, according to Kahl (2019), revised; used references: Scholz et al. (2018), Soil Association (2020); Farmer's Business Network, Inc.(2020), (USAID) (2020), Buller et al. (2019)

Example	Summary of emphasis	Basic structure	Costs, sponsoring and funding models

Outside Germany	Farmer Field Schools	A form of adult education where farmers learn optimally in groups from field observation and experimentation. In regular facilitated meetings (often weekly) groups of neighboring farmers observe and discuss dynamics of their cropping ecosystem.	It was developed from the Food and Agricultural Organization of the United Nation (FAO). The program started 1989 in Indonesia and rapidly expanded.	• Financed by international donor programs or temporary projects
	Innovative Farmers	Farmer led Innovation approach: Network of farmers and growers who are running on-farm trials, on their own terms. Groups of farmers can work directly with a researcher to design 'field lab's: the group decides on the topic and the researcher helps design a trial.	It was launched in 2015 in Schottland. It is a partnership programme, with Linking Environment And Farming, Innovation for Agriculture, Organic Research Centre and Waitrose, led and managed by the Soil Association. Soil Association is a registered charity and certification business made of several entities	• Free for farmers • Innovative Farmers is part of the Duchy Future Farming Programme, funded by the Prince of Wales's Charitable Fund through the sales of Waitrose Duchy Organic products. • The network is backed by a team from LEAF (Linking Environment and Farming), Innovation for Agriculture, the Organic Research Centre and the Soil Association. • There are different

				sponsors supporting the program • Many of the UK's top agri-research organisations have been involved in field labs, or have registered their interest in collaborating with groups.
	Stable Schools	Participatory advisory approach: individual farm and herd strategies through a participatory process using farmer groups (5-6 farms) for mutual advice and common learning. Facilitated, monthly groups meetings on a private farm of a group member.	The concept was developed in 2004 in Denmark by a large group of organic farmers.	• Project funded
	The RIO approach	Specific form of participatory technology assessment that adopts design of both the technical and social features of societal systems for production and consumption. Definition of the problem and the solution takes	Reflexive Interactive Design approach was 2001 initiated in the Netherland. It was applied and tested in several projects like the Well-Fair Eggs project. Buttom – up approach facilitated from above.	• Several project funding • Initiated to be a relatively simple and cheap financial instruments that governments can help to create a conducive environment

		places in a reciprocal and iterative argumentative exchange.		
	Farmers Business Network SM	Farmers wanted to develop an independent, unbiased, and objective farmer-driven information source — no marketing fluff. They knew that if they could share their agronomic precision data with one another, they could all make better decisions on seeds and agronomics.	The Network started 2014 with farmers, technologists, scientists and entrepreneurs. As a member, you get access to all of the *FBN* analytics products, crop marketing opportunities and Profit Center, *FBN Direct* product pricing, financing services, and events.	• Membership fees: 700$ for 1 year; 1100$ for 2 years; 2500$ for 5 years
	Farmer to Farmer Programm	Support farmers and agribusiness professionals in developing countries to improve their livelihoods and food security by sharing knowledge and skills with farmers. Farmer-to-Farmer sends U.S.-based volunteers on technical assignments to provide hands-on training to communities, cooperatives, agribusinesses, and educational institutions.	The Farmer-to-Farmer Program leverages the expertise of volunteers U.S. farms, educational institutions, cooperatives, private agribusinesses and nonprofit farm organizations to respond to the local needs of host-country farmers and organizations. Farmer-to-Farmer volunteers work in over 30 countries around the world. Each volunteer assignment is facilitated by one of eight U.S.-based NGOs that implement the Farmer-to-Farmer Program	• is USAID-funded and implemented by ACDI/VOCA, Catholic Relief Services, CNFA , IESC, Land O'Lakes Venture 37, National Cooperative Business Association CLUSA International, Partners of the Americas, Winrock International, Grameen Foundation, and High Atlas Foundation.
In Germ	Mentoren-Netzwerk	Cooperative advisory	An online networking platform	• First two sessions gratis, 3rd session

	Ökolandbau [*Mentor network: Organic farming*]	approach: Organic farmers offer mentoring to those seeking advice, sharing their experience and knowledge; exchanging information on farm situations and offering support with structural issues.	(https://mentoring.bio/) initiated by the Kompetenzzentrum Ökolandbau Niedersachsen GmbH [*Lower Saxony Organic Farming Competence Center Gmbh*] and the Bäuerliche Bildung und Kultur gGmbH [*Agricultural Education and Culture GmbH*] open to farmers working in northern Germany.	onwards, 75€ an hour • The network is financed by the Software AG Trust Fund
	BioRegio Betriebsnetz [*BioRegio regional organic farms network*]	Network of typically regional, best-practice and demonstration organic farms in Bavaria, focusing on knowledge transfer at collegial gatherings, farm tours and educational events at participating farms with the intent to expand organic farming and strengthen existing enterprises.	A project supervised by the Bayrische Landesanstalt für Landwirtschaft [*Bavarian Minstry of Agriculture*] (LfL) and carried out by the above in cooperation with the Landesvereinigung für den ökologischen Landbau in Bayern e.V. [*Bavarian Association of Organic Farmers*] (LÖV)	• Participation in gatherings, tours and educational events is free • Funded by the Bavarian Ministry of Nutrition, Agriculture and Forestry, implemented by the *BioRegio Bavaria 2020* initiative • BioRegio farms receive an expense allowance from the state
	Hopfenring e.V. (*Hops Circle Society*)	Advisory and educational offerings, both individual and group formats for members.	The Society is a member of the Landeskuratorium für pflanzliche Erzeugung in Bayern e.V. [*State Advisory Board for Vegetable Cultivation*]	• Membership fees: 22€ + 1,29€ per hectare of cultivated hops • Additional cost for probes such as soil analyses

				• No state funding
	Öko-Beratung Baden-Württemberg. e V. [*Eco-Consulting Baden-Wuerttemberg*] (ÖBBW e.V.)	Offers individual advisory services as well as networking with researchers, scientists, institutes and businesses.	Cross-association advisory organization in Baden-Wuerttemberg.	• Consultancy fees 104€ /h • Plus, travel costs • State funding available

Materials and Methods

Case study

To understand the extent of regional farmers' demand for network approaches, such as farmer's discussion groups a single case study (Yin, 2018) of a *Cropping School* in Brandenburg, Germany was explored.

The *Cropping School* was initiated with funds from the European Agricultural Fund for Rural Development (EAFRD) and will face the challenge of how to continue after the funding period. It started with nine actively involved farmers and grew to 21 actively involved farmers within one year. Participants agreed to tackle legume cropping and nitrogen management as the main topics in the first year. In the second year, they conducted two on-farm field tests on legume management and varying tillage systems. When appropriate, meetings or field tests are supported by visiting scientists or professional advisors. All activities are facilitated by a network coordinator and supported by an agricultural-technical assistant.

A case study protocol was designed to guide the investigation, including research questions (problems and objectives of the analysis) and the methods of data collection (Yin, 2018; Mayring, 2002; Bochardt et al., 2009). Costs of all *Cropping School* activities were assessed and face-to-face interviews with network participants were performed.

Cropping School activities and their calculated costs

To estimate total costs per network participant, the costs for the services and activities shown in Table 2 were calculated for the *Cropping School* case study.

Tab. 2 Cropping School services and activities

Services	Activities
Staff	• network coordination • plan, organize and moderate regular meetings (4 meetings within the 8-month calculation period at approximately 3.5 hours per meeting) • field assessments • conduct and analyze on-farm trials (3 - trials and 1 field assessment within the 8-month calculation period) • generate reports (meeting protocols, results reports, scientific status quo)

	• public relations • network administration (public procurement, etc) • networking: participation in various events to a) maintain and establish contact with cooperation partners; b) keep abreast of current agricultural issues/topics
Scientific/advisory expertise	• attend network meetings
Travel expenses	• travel to and from network meetings or networking events
Materials	• moderation material and paper for network meeting reports • project flyers and posters • soil assessment and/or plant analyses (material and lab costs) • hospitality costs • **costs not calculated include** office supplies, stamps, current internet, telephone, room rental and acquisitions, i.e. telephone, computer, desk and chair

From January 2019 to August 2019, labour hours required for all activities were documented. All other costs, such as expert fees, travel and materials were recorded from April 2018 to August 2019. Personnel costs were calculated at the average gross rate for German public service staff members.

Farmers' willingness to pay

A farmer's willingness to pay for services is an essential component in assessing potential financing and business models for *Cropping Schools*. Guided face-to-face interviews were conducted with 10 farmers, representing 50% of *Cropping School* participants. The sample was selected according to membership duration and participation intensity during network meetings.

Results and Discussion

The case study reveals a high demand for a regional farmers' network, like the *Cropping School*, that supplements other advisory services (individual consulting or field days). In the case study, group of participants doubled in the first year. More farmers would like to join the *Cropping School* or establish more *Cropping Schools* in their region, suggesting a high demand for *Cropping School* services. In the long term, *Cropping Schools* cannot rely on permanent funding that provides free services. Farmers will need to develop self-sustaining business models financed by network members.

The calculated costs for a *Cropping School* ran to approximately 1,500€ per year, per farmer (with 20 farmers per network) (Table 3).

Tab. 3 calculated costs for a Cropping School

	Network activities with individual services	Network activities without individual services
Required labour (hours)		
Project coordination	402	158

Project administration	49	49
Public relations and networking	100	100
Training of staff	3	3
Total staff hours	**554**	**310**
Costs		
Labour costs	17.174,00 €	9.610,00 €
Costs of experts (scientists or advisors)	1.925,00 €	1.925,00 €
Travel costs	2.500,00 €	1.890,00 €
Material costs	2.670,00 €	1.090,00 €
Total Costs per month for a network participant (with currently 20 members)	**130,00 €**	**75,00 €**

*****valued at 31€ per hour.

If costs were calculated without practical research services, i.e. conducting on-farm trials, assessing fields, analyzing laboratory results and generating reports, come to approximately 900€ per year, per farmer. Other farmers' networks in Germany quote prices from 75€ to 104€ per hour for facilitating group meetings, without practical research services (Table 1). Four meetings of 3,5 hours would cost 1,000€ to 1,500€ per year, per farmer. These results show that the cost of the *Cropping School* are similar to the membership fees in established networks. A self-financed business modell of the *Cropping School* can be considered as a realistic option.

Interviews showed that all ten *Cropping School* participants interviewed were interested in a continuation of the network once project funding was depleted. All participants were also willing to share the costs, as long as some funding from project sponsors was included. Six farmers considered network continuation via project funding more feasible. Only four participants considered to independently shoulder all network costs and three of them are willing to cover more or less the total cost (Figure 1). However, interviews also revealed that all surveyed participants would contribute to enable a continuation of the network in combination with additional funding. One option being state, national or EU-funded projects, which, in turn, depending on further programs. Alternatively, existing advisory organization could offer such network services. Thereby the networks would benefit from certain efficiency gains within the existing services of these organizations.

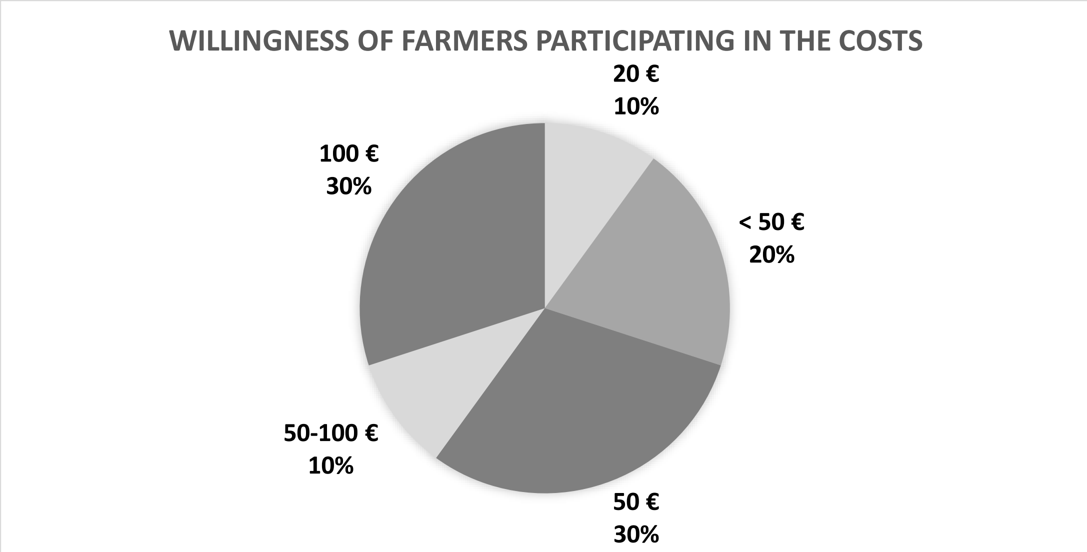

Fig. 1 How much are farmers willing to pay per month for a Cropping School?

In Brandenburg situation state-funded advisory organizations or farmers' associations do not exist. The advisory systems are dominated by private enterprise consultancies. Farmers' networks or group advisory formats are unknown. In comparison with other farmers' networks approaches (within and outside Germany), this suggest the following business option to institutionalise the *Cropping School* in Brandenburg:

I) establish a new/own association or which is financed by membership fee and/or funding programs

II) join existing private associations

III) join academic research project as project partners, no self organized network

All three options have advantages and disadvantages for a self-sustained network.

Tab. 4 Advantages and Disadvantages of busines models

Option	Âdvantages	Disadvantages
I) Own association	• Cropping School group of the study case knows each other and can continue to exist • Cooperation with different research institutions in Brandenburg established • Group determines own mission	• Knowledge, human resources and time requirements to establish the legal structure of an association

		statement and topic setting • Regional networks with cross-association advisory organization are possible • Financing through membership fee and/or funding programs possible	
II)	Join existing association	• Existing structures can be used • Cropping School group of the study case has no need for knowledge, human resources and time to establish a legal structure of an association • Larger associations mostly use financing options like membership fees, donations, sponsors or funding programs: this could reduce cost for farmers (membership fees) compared to option I	• Association's mission statement must be adopted • Topic and group composition can be determined by the association • Cross–association advisory organisations do not exist in Brandenburg; Cropping School group of the case study are operate cross – association • Risk of not finding a model for cooperation with research partners
III)	Join academic	• Guaranteed cooperation	• no permanent network structure; always

research project	with research associates • No membership fee for farmers	limited in time and often with only one thematic topic • research projects will not interest all participants in a group • Universities should not compete with advisory services (distortion of competition) – long-term advisory services are not traditionally part of University structures in Germany.

Conclusion

The case study reveals a high demand for regional farmers' networks, in addition to individual advisory services, in Brandenburg, Germany. Farmers appreciate the opportunity to exchange and interact with colleagues and experts. This interaction and mutual learning empowers farmers to venture new cropping system methods. Results suggest three potential business models for regional farmer's networks in Brandenburg, Germany. Establishing an own association which is financed by membership fees and/or funding programs seem to be the most promising approach. But results also show that farmers are not willing to bear the entire cost of these services alone. As these networks are an excellent tool to encourage learning, while enabling farmers to identify farming system problems and to take action for improvement, we recommend further investigation into different funding models.

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