Social and Technological Transformation of Farming Systems:

Diverging and Converging Pathways

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Workshop 3.4: Boundary spanning between agroecological and conventional production systems: implications for pathways towards more sustainable production

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The boundary between agroecological and conventional production systems can be described as one of tension at an ideological level and some synergy at the scientific and applied level. Agroecological and conventional production systems have different belief systems, values and understanding of the approaches required to achieve their goals but there are at the same time some overlaps of knowledge systems and multiple examples of shared practices. In recent years, the conventional community has started to incorporate some agroecological principles into conventional production systems in its pursuit of more efficient food production and reduced environmental impacts while the agroecological community has focused more on promoting ecosystem and human health. The conventional community's approach might be characterised as following an incremental transition pathway within a specific set of parameters, while the agroecological community favours a pathway of systemic change from the current norm, in which changing belief systems plays a large part. The specific parameters for conventional producers could include environmental policy and regulation, market price and financial return while agroecological production prioritises a holistic approach which delivers multiple outcomes including soil health, the delivery of ecosystem services and community resilience. The case has been made for the need to change belief and value systems before truly sustainable practice can be achieved, yet also that more sustainable practice can influence or induce a change in belief systems. Equally it can be argued that a shift in the direction of an agroecological approach and more sustainable production can be made on farm without a complete ideological shift by land managers. This workshop aimed to explore this boundary interaction between agroecological and conventional production systems, particularly with respect to underlying belief systems, incremental and systemic transition, the implications for farmer learning and facilitation, and for sustainable production (optimising outcomes in terms of ecosystem services). It invited theoretical, empirical and methodological papers from social and natural science disciplines that address the following questions:

1) What are the recent advances in understanding the different belief systems, values and goals that underpin agroecological and conventional production systems and their relationship to sustainable food systems?

2) Is it possible, and if so to what extent, can agroecological and conventional communities share their knowledge systems whilst maintaining their integrity?

3) Can boundary spanning result in systemic change, if so, how might this be assessed, and facilitated?

4) Revolution vs. evolution: Is systemic change always necessary? To what extent can more sustainable outcomes be achieved (i.e. optimising outputs of ecosystem services) through an incremental transition towards agroecology?

Agriculture models at the crossroads of farming systems, food systems and territorial dynamics

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Abstract: Different agriculture models can be developed to deal with sustainability issues. The objective of this paper is to present a new analytical framework allowing the identification of key agriculture models at the crossroads of farming systems, food systems and territorial (local) dynamics. The first dimension of this framework is based on the distinction between three key types of farming systems: synthetic inputs-based, biological inputs-based and biodiversity-based. They are more or less dependent on exogenous inputs and ecosystem services. The second dimension is based on the identification of how each of these three types of farming system interacts with global food systems and territorial dynamics i.e. circular economy, local food systems and integrated landscape approaches. Our framework makes it possible to specify agriculture models corresponding to a type of farming system and to the nature and level of its interactions with its socio-economic context. Finally, in considering six key agriculture models we sketch out key associated scientific issues.

Keywords: Biodiversity, ecosystem service, biological input, food system, industrial ecology, landscape

Introduction

At the end of the 20th century there was a maelstrom of agricultural crises involving issues of energy, water, biodiversity, climate change, economics and food security (Capone et al., 2014). Organic farming systems are often considered as a possible model for sustainable agricultural systems (Niggli et al., 2008) with intense discussion about the possible production level (Seufert et al., 2012). On the other hand many people (researchers, politicians, agricultural agencies….) consider that either integrated, conservation or precision agriculture are also ways to improve the sustainability of farming systems (FS) (e.g. Garbach et al., 2016). However, each of these categories encompasses a wide diversity of FS exhibiting different environmental and socio-economic performances.

Social science research distinguishes between two main paradigms underpinning pathways towards sustainable agricultural systems: "shallow *versus* deep sustainability" (Hill, 1998); "weak *versus* strong ecological modernisation of agriculture" (Horlings & Marsden, 2011); and "life sciences *versus* agro-ecological vision" (Levidow et al., 2012). Elaborating on these conceptualisations, Duru et al. (2015a,b) characterise them by considering the role and status of exogenous inputs and ecosystem services (ES) in the agricultural production. In their analysis the first pathway seeks to deal with environmental issues through increasing the efficiency of exogenous input use (e.g. fertilisers, pesticides and water), recycling waste or by-products of one sub-system inside another (Kuisma et al., 2013) as well as applying sound agricultural practices (Ingram, 2008) or precision-agriculture technologies (Rains et al., 2011). A variant is based on replacing synthetic with organic inputs (Singh et al., 2011) or genetically modified organisms (Godfray et al., 2010). In accordance with the Hill (1998) classification, Duru et al. (2015a,b) call this approach "efficiency/substitution-based agriculture". This usually consists of incrementally modifying crop or animal management practices in specialised systems so as to comply with environmental regulations while preserving economic competiveness (Duru & Therond, 2014).

The second main pathway in the Duru et al. analysis aims to strongly enhance ES to agriculture provided by biodiversity (Zhang et al., 2007). These ES depend on the level and management of biodiversity at field, farm and landscape levels (Kremen et al., 2012). Accordingly, Duru et al. (2015a) have named this approach "biodiversity-based". It seeks to develop diversified cropping and FS or even landscapes to enhance ES for both farmers and society while drastically reducing the use of exogenous inputs. It introduces a paradigm shift in the vision of agricultural innovations and systems, especially as regards their objectives and expected performances (Caron et al., 2014). It leads to a strong modification of the vision and thus the role and the management of the environment (nature) in agricultural production (Levidow et al., 2012). Developing a biodiversity-based agriculture requires the extensive redesign of FS. Of importance is the fact that, in this agriculture, practices for increasing resource use efficiency and recycling are also implemented when using inputs. Duru et al. (2015b) highlight that development of a biodiversity-based FS requires both changes in natural resources management strategies as well as in agricultural supply chains.

Our objective is to enrich the above mentioned classification for identifying different key agriculture models at the crossroads of farming systems, food systems and territorial dynamics. In the following section we clarify the main agro-ecological differences between synthetic inputs-based, biological inputs-based and biodiversity-based FS according to the place and function of ES or of exogenous inputs in the agricultural production process. For each of these three types of FS we then identify their possible interactions with global food systems and territorial dynamics and in turn define typical agriculture models corresponding to a type of farming system and to its interactions with its socio-economic environment. Finally, we sketch out the key scientific issues associated with each agriculture model.

Farming systems and ES

Until the end of the 20th century, farmers were encouraged to develop the most suitable conditions for crop and animal growth. Most of them accordingly used high production level breeds to increase the "growth-defining" factors (potential production level for given climate conditions) and implemented agricultural practices to control the "growth-limiting" abiotic factors (water and nutrients) as well as the "growth-reducing" biotic factors, i.e. negative pest effects (Ittersum & Rabbinge, 1997). In addition they endeavoured to improve the physical production environment: (i) soil structure determining water transfers, root growth and functioning and, in some cases, (ii) local climate conditions (e.g. temperature). Management of yield-increasing and yield-protecting inputs determined the level of growth-limiting and reducing factors and the input-use efficiencies.

The Millenium Ecosystem Assessment (2005) showed that human welfare strongly depends on ecosystem goods and services. Zhang et al. (2007), then Bommarco et al. (2013) and Duru et al. (2015a) clarified the status of ES in agricultural production, highlighting that regulation services determining soil fertility (soil structure and nutrient cycling), water storage and pest control are the key services provided by ecosystems to agriculture. Duru et al. (2015a) established the link between the theory of growth-defining, limiting and reducing factors of Ittersum and Rabbinge (1997) and the theory relating to ES provided to farmers (hereafter “input ES”). It is shown that the share of agricultural production depending on ES (versus exogenous inputs) depends itself on the paradigm on which FS are based: inputs-based or biodiversity-based FS (Figure 1). It is important to keep in mind that even inputs-based FS depend on ES (Bommarco et al., 2013).

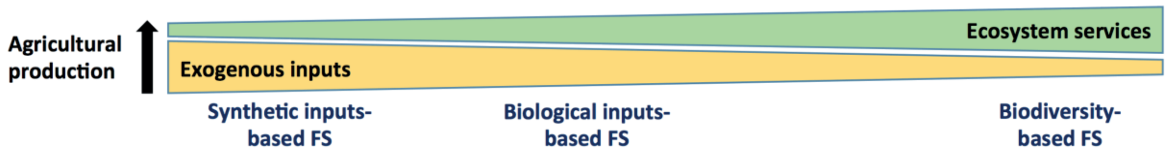

Figure 1. Types of farming systems (FS) according to the share of agricultural production derived from ES and anthropogenic inputs

Synthetic or biological inputs-based FS seek to address economic constraints and environmental regulations by means of optimising inputs according to the spatio-temporal plant/animal requirements and in turn to limit pollution (Table 1). In order to deal with sustainability issues and regulations, inputs-based FS implement an efficiency-based modernisation pathway (cf. introduction). One of the challenges of these synthetic inputs-based FS is to accurately assess the level of input ES in time and space needed to optimise the necessary level of additional anthropogenic inputs required to reach the targeted production level. Precision agriculture technologies based on sensors positioned in the soil, machinery, drones, planes and satellites permit the monitoring of the dynamic level of different variables and the optimisation of required input applications. They are well developed to deal with nutrient cycling - above all nitrogen - and weeds (e.g. weeding robot; targeted pesticide applications). In addition, farmers use cultivars and animal breeds which are less sensitive to limiting or reducing factors while exhibiting the same level of or better potential yields (defining factors). All these technologies may allow FS to increase input use efficiency, reduce environmental impacts and, depending on the technology costs, economic performance. The amortisation of these technologies may lead farmers to continue to increase their farm size in order to reach suitable economies of scale. Regulations can lead farmers to introduce more substantial changes such as resort to cover crops in nitrogen-sensitive areas. In this case, cover crops are sown during the bare soil period according to regulations relating to sowing and removal dates.

Considering societal reluctance to accept synthetic pesticides as well as human and ecosystem health issues, some farmers managing inputs-based FS seek to use more “environmentally friendly inputs” while still managing a specialised farming system. As such, they implement a substitution-based modernisation pathway to develop “biological inputs-based” FS. Beyond the classical use of organic fertilisers as substitutes for inorganic, new practices related to biocontrol are developing to mimic the ecological functioning of diversified agroecosystems. By implementing industrially developed natural enemies (e.g. trichogram in maize) and other service-providing organisms (e.g. azotobacters, probiotics, arbuscular mycorrhizal fungi), soil bio-stimulants and bio-inoculants, farmers seek to amplify ecological processes underpinning ES which naturally arise in biodiversity-based ecosystems (Phillipot et al., 2013). They can also use bio-pesticides to reduce the eco-toxicity of synthetic pesticides. Moreover they can grow cultivars selected to stimulate beneficial biological soil activity (Singh et al., 2011). All these technologies, whether or not they have a resilient effect, might enable the development of input ES in the short, medium or long term (Figure 1).

In biodiversity-based FS, developing input ES requires developing species/breeds diversity (e.g. intercropping, diversified field margins as well as crop sequences) and of soil cover (cover crops*)* while minimising disturbances of beneficial biological processes due to tillage and synthetic inputs use (Table 1) (Duru et al., 2015a). One of the challenges is to develop and manage planned biodiversity from fields and field borders (e.g. flower strips) up to the farmland area for developing naturally-present associated biodiversity which acts as a service provider while limiting the development of detrimental associated biodiversity (pests) (Fahrig et al., 2011). When these FS use synthetic or biological inputs to increase the production level beyond the level supported by input ES alone they have to use them sparingly so as to not reduce the expected short- and long-term benefits of input ES (Pisante et al., 2015).

Table 1. **Key features of three types of farming system archetypes (FS)** *(adapted from Duru et al., 2015).*

FS archetypes	Main objective and strategy	Nature of farming practices
Synthetic inputs-based	Increase of competitiveness and reduction of pollution via improvement of input efficiency ("Ecological intensification")	Standardised practices in specialised FS (small number of crops) based on external inputs
Biological inputs-based	Increase of competitiveness and reduction of impacts on biodiversity and human heath via substitution of synthetic by biological inputs	Standardised practices in specialised FS (small number of crops) based on external biological inputs. Possible integration with livestock
Biodiversity-based	Increase of competitiveness through development of biodiversity and ecosystem services ("Ecologically intensive agriculture")	Site-dependent agroecological practices in FS based on diversified crops and possibly on integrated crop-livestock interactions, allowing greatly reduced use of anthropogenic inputs

As shown by Biggs et al. (2011) these FS have to manage three key properties of the agricultural ecosystem to develop the production level and resilience of ES: diversity-redundancy, connectivity and state of slow variables. While the first is commonly identified in the literature on agroecosystems, management of the latter two are less classically highlighted. Connectivity between biophysical entities determines circulation of materials (including organisms) and energies and thus the system's performance. It determines species dispersion capabilities between habitats (Tscharntke et al., 2005). The state of slow variables (e.g. soil organic matter, ecological networks) determines dynamics of associated fast variables (e.g. nutrient and water cycling, biological regulations). Short-, middle- and long-term management of slow variables (e.g. soil organic and biological state) determines day to day (soil nitrogen and phosphorous availability), year to year (soil structure) as well as long-term system functioning (dynamic of soil organic matter). While managing these three properties over different scales, farmers may strongly increase ecosystem integrity, i.e. its self-organising capacity (Müller et al., 2000). It is important to keep in mind that the use of living biological inputs (e.g. industrially developed natural enemies) in a biological inputs-based farming system can be a step forward towards the development of a biodiversity-based farming system: the farmer starts to develop a production system based on biodiversity even as it is imported into the agricultural ecosystem.

Interactions between farming systems, food systems and territorial dynamics

FS are embedded into food systems representing diverse sets of institutions, technologies and practices for producing, processing, packaging, distributing, retailing and consuming food. Food systems influence not only what is being consumed and how it is produced and acquired, but also who is able to eat and how nutritious their food is (Capone et al., 2014). Institutions and practices for management of natural resources (water, soil, biodiversity) used by agriculture, i.e. the social structure and dynamics of social-ecological systems, interact with farming and food systems (Foran et al., 2014). Global food systems (e.g. soybean and grain wheat market) have developed in recent decades with a strong impact on the homogenisation of national food systems (Khoury et al., 2014) as well as on health (e.g. Monteiro et al., 2013). While FS are embedded in global food systems, they can also be more or less embedded in different territorial (local) dynamics (e.g. circular economy) (Figure 2).

For each of the three types of FS described above, we characterise the main types of interactions they may develop with global food systems and different key territorial (local) dynamics (including local food systems).

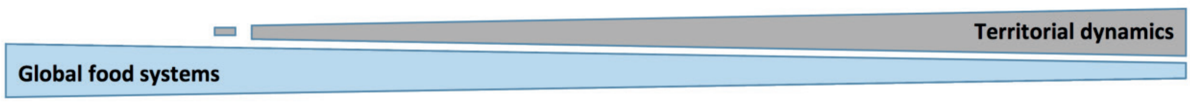

Figure 2. **Schematic of the relationship between global food systems (including agricultural non-food commodities) and territorial dynamics (circular economy, local food systems and integrated landscape approaches) in which farming systems are more or less embedded**

Synthetic inputs-based FS are generally embedded in and mainly interact with large food supply chains in which power is concentrated in large retailers (Marsden, 2011). In the context of the strong development of the composites market (versus agricultural products) and the bio-economy, raw agricultural products are sold as commodities on the market - just like any other product in the marketplace (O'Kane, 2012). Accordingly, evolution of this type of FS is mainly driven by these global food systems. Economic resilience of these FS to price variability and biophysical hazards can be supported respectively by contracts and insurance schemes, both provided by global food supply chains. These insurance instruments may lead farmers to increase the share of riskier cash crops resulting in an increasing share of monocultures (Müller & Kreuer, 2016). Due to integration in the dynamics of large-scale food systems these FS are often poorly connected with local natural resource management issues and strategies, leading to conflicts regarding e.g. water shortages due to irrigation, water quality due to pollution, and erosion due to bare soils. A typical example of this decoupling of global food systems from local environmental issues is the world soybean market, which grew strongly during the 1990's and led to high environmental impacts in regions where soybean is grown (e.g. pesticide pollution and deforestation) as well as in those where it is used as feed for specialised and concentrated livestock enterprises (nitrogen emission) (Billen et al., 2014).

Biological inputs-based FS are most often also embedded in and mainly interact with large food supply chains providing biological inputs (e.g. bio-stimulants and bio-pesticides, exogenous organisms) and selling raw products that feed the global composite and bio-economy markets. However, they may evolve according to opportunities to substitute synthetic with biological inputs provided by both large-scale supply chains or by local dynamics. Development of a circular economy at a local scale may offer such opportunities. A circular economy aims at limiting the use of and protecting finite natural resources, by the improved closure of material and energy cycles. It seeks to develop recycling loops between economic agents: outputs or wastes of one economic agent becoming the input of another or others. In such local dynamics, environment is considered on the basis of concerns about resource scarcity, pollution and waste limitation. This form of territorial integration of economic activities may allow for examples to develop: (i) the use of locally produced organic matter and nutrients derived from wastes to improve the organic soil state and associated SE; and (ii) the use of agricultural products for energy purposes (dedicated crops or residues such as straw).

In this form of territorial integration, the development of trading between specialised livestock and crop farms (e.g. especially organic fertilisers like manure, straw or even animal feed), without questioning crop rotation, is a model of circular economy. Logistical (transport, transformation) and economic issues (market stability) can be managed directly by farmers or by the food supply-chain (Moraine et al., 2016). Trading can also be developed between FS and other operators of the food supply-chain (e.g. food processing, transporting) or with other sectors of activity (e.g. production of organic 'wastes') (Nitschelm et al., 2015). Accordingly, while embedded in large supply-chains, biological inputs-based FS can also be strongly integrated into the territorial dynamics of a developing circular economy. For example, an organic farming system with low levels of crop and animal biodiversity can be strongly integrated into local trading between farms so as to acquire organic fertilisers (e.g. Fernandez-Mena et al., 2016).

In biodiversity-based FS, farmers develop planned diversity (plants and animals) for improving input -ES and -self-sufficiency. When there is no other solution, or if prices are attractive, products are sold through large-scale food supply-chains as seen above. The lack of attractive markets for some key crops required to strongly diversify cropping systems is a major limitation to the development of such FS (Meynard et al., 2013). Development of trading between crop and livestock FS allowing diversification in cropping systems (e.g. introduction of alfalfa, grain legumes, grasslands) constitutes a first level of territorial integration offering opportunities for diversification of biodiversity-based systems. Such trading between crop and livestock systems can offer opportunities to improve soil organic matter through application of manure as well as to enhance biological regulations through spatiotemporal diversification. Here, the most important concerns are the health/integrity of soils, plants and livestock as well as collective action issues (e.g., craftsmanship, stewardship).

Another form of territorial integration corresponds to the development of local markets (including collectively organised short food supply chains). The challenge can consist of developing "territorialised food/non-food systems" that support the development of a local diversified agriculture meeting local consumer and lifestyle demand and even human health issues. Their development may be part of a larger territorial development project where agriculture is one of the key sectors involved. A higher level of integration of biodiversity-based FS within territorial dynamics can occur when local actors seek to develop sustainable landscapes that jointly supply multiple ES (Mastrangelo et al., 2014). The challenge consists of developing collective governance of the diverse land managers so as to design the spatial distribution of land use (crop-grassland pattern) and semi-natural habitats which may increase ES depending on the composition and configuration of the landscape (e.g. biological regulations, mass and liquid flow regulations). This requires a landscape design approach (Nassauer & Opdam, 2008) for example for water management (Murgue et al., 2015), strong territorial crop-livestock integration (Moraine et al., 2016), hedgerow networks (Groot et al., 2010) or biological regulations (Steingröver et al., 2010).

As in the case of biological input-based FS, biodiversity-based FS can also be involved in a circular economy. Development of a circular economy and of local food systems offering important diversification opportunities to local FS coupled with integrated landscape management corresponds to the highest level of territorial integration i.e. the development of an integrated landscape approach (Reed et al., 2016). It may permit the development of an "*eco-economy paradigm which replaces and indeed relocates agriculture and its policies into the heart of regional and local systems of ecological, economic and community development*" (Marsden, 2012). Here the main concerns are about natural resources management, landscape/ecosystem integrity, human welfare and local social dynamics. However, some agricultural products may still be sold through the global food system. Local and global markets are then considered as complementary and thus co-exist.

From diversity of agriculture models to knowledge gaps in agronomy

Considering the three types of FS and their possible interactions with local to global food systems and local dynamics, it is then possible to identify different key "models" of agriculture. Here, each agriculture model corresponds to a type of farming system and its interactions with its socio-economic environment (Figure 3). Some are developed, others correspond to niches or represent potential forms of agriculture within a given region or country.

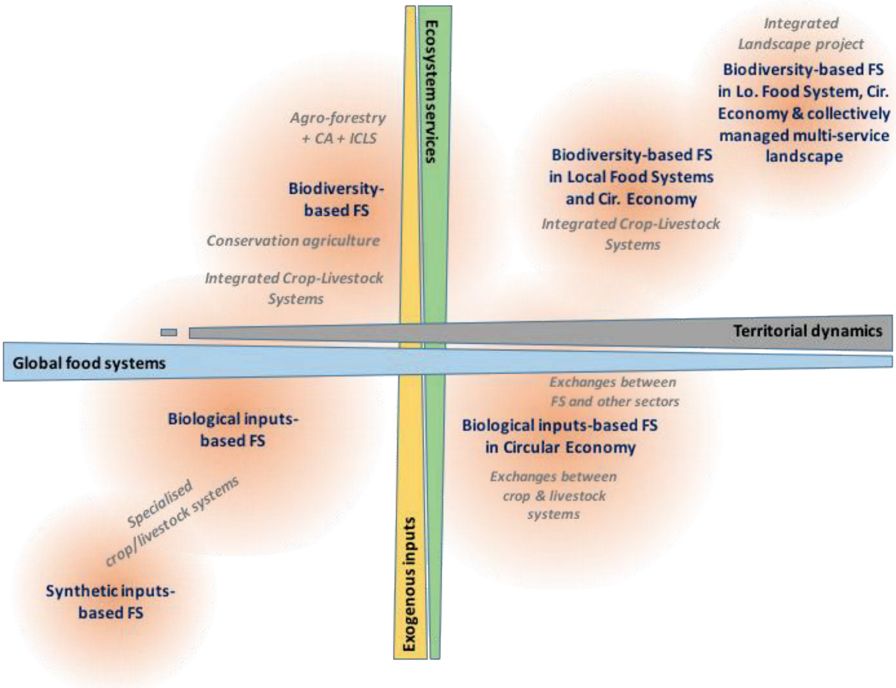

Figure 3. **Six key forms of agriculture (in blue) in which farming systems (FS) are more or less based on ecosystem services vs. anthropogenic exogenous inputs (Y-axis) and connected to global food systems or different territorial dynamics (X-axis). Iconic examples are presented in grey. CA = Conservation Agriculture; ICLS = Integrated Crop Livestock Systems**

Synthetic inputs-based FS embedded in global food systems corresponding to specialised cash crop and livestock farms (lower left quadrant Figure 3), is the dominant agriculture model in Western Europe (Levidow et al., 2014). To increase (weak) sustainability of this type of agriculture, much research focuses on developing smart agricultural technologies (e.g. genetic engineering, precision farming). Through integration of up-to-date scientific knowledge within decision support systems there exists a potential for improving agricultural as well as the environmental performance (reducing soil, water resources and atmospheric pollution) of this type of agriculture model. In this case, changes generally require only incremental adaptations (Park et al., 2012).

Biological inputs-based FS are strongly promoted by the European Union (Levidow et al., 2014). They correspond to two agriculture models (lower left and lower right quadrants Figure 3). In both models the use of living biological inputs for biological control are in their infancy (e.g. Philippeau et al., 2014). While the effects are well known and efficacy has been demonstrated for some uses of iconic living inputs such as inoculation of *Rhizobia* into leguminous plants (Philippeau et al., 2014), actual effects at field level of many biological inputs such as bio-stimulants have not been soundly demonstrated. Moreover, their resilience is generally low, leading farmers to apply them regularly (e.g. annually). One reason may be that these products are used in the same way as synthetic ones while "*being biological these products have to be applied in accordance with their ecological requirements"* (Alabouvette et al., 2006). Furthermore, it is still necessary "*to carefully study the effect of inoculum type, application rate and time of application to ensure efficacy of biological control"* (ibid). The development of biological inputs-based FS embedded in a local circular economy is strongly supported by regional and national policies (e.g. European Union) which promote the development of circular economies for increasing the economic and environmental performance of economic activities (including agriculture). Much research is emerging in the field of industrial ecology (biogas production, recycling…). Moving from farm to landscape level for coupling nutrient and water cycles requires coordination between agricultural actors and those in other sectors. Considering specificities of food supply-chains, Fernandez-Mena et al. (2015) argue that such research should be developed in order to provide methods to analyse, assess and design recycling loops and to explore circular economy options in these particular complex social-ecological systems. Development of this type of agriculture model usually requires system adaptations (Park et al., 2012).

In accordance with possible interactions between biodiversity-based FS and global food systems or territorial dynamics, three main associated agriculture models can be identified. The first corresponds to FS developed in socio-technical niches (e.g. farmer collectives) such as those related to conservation agriculture, agroforestry, integrated crop-livestock systems and self-sufficient grassland-based livestock systems (Figure 3 top-left quadrant). In these systems, farmers sell their products within global food systems or via direct markets (to consumers or other farms). Development of these FS raises questions about how to manage the “transformational” transition from a specialised system to a well-established diversified one. During this transition variability in ES may significantly increase until slow variables and ecosystem structure reach a state permitting the provision of ES at the expected levels and degrees of biophysical resilience and stability (Duru et al., 2015a). For example, positive effects of conservation agriculture, through implementation of its three principles (no-tillage, cover crops and long rotations) may emerge after more than ten years.

During the transition ambiguous biophysical phenomena can be observed. For example, landscape complexity with various and well-represented semi-natural habitats may exhibit more diversified natural-enemy communities but may also provide better and more abundant overwintering sites for pests (Duru et al., 2015a). The particularity of this type of FS is that if ecological principles are generic, management practices are highly site-dependent (Giller et al., 2015). To support farmers in managing this transition research on agroecology has to develop knowledge that farmers can use in order to choose the best practices they can implement, considering the characteristics of their production situations. The characterisation of the different species/breeds that farmers can introduce (cash crop and “service crops”) and their mixtures through functional ecology approaches (response and effect plant traits) is a promising way to provide operational knowledge (Duru et al., 2015a). New technologies of communication and information can be mobilised to render scientific knowledge accessible and operational as well as collecting feedback from farmer experiences (Dowd et al., 2014). Integrated participatory design and assessment of diversified cropping and FS methodologies also have to be developed (Duru et al., 2015a). Breeding of “service species” selected to provide a given function (e.g. soil structuration) in mixture or sequence with cash crops is also a key research area.

The second form of biodiversity-based agriculture is when diversified FS has developed significantly in a given territory thanks to the development of local food systems (e.g. integrated crop-livestock system in Figure 3). Beyond research questions regarding management of diversified FS, the management of a local food system in the light of existing global food systems is an issue for socio-economic research but also for agronomy regarding the development of agricultural systems promoting soil, plant, animal, ecosystem and (in turn) human health.

Development of an integrated landscape approach combining collective landscape management with local food systems and a circular economy correspond to the third agriculture model involving biodiversity-based FS. In this case, research has to provide adapted knowledge and participatory methodologies to support the collective design of multi-service landscapes i.e. crops-grasslands-semi natural habitats patterns providing expected levels of targeted ES. One key research issue here is to clarify the effects of landscape configuration and composition in relative to the effects of cropping systems (field level) for different ES during the farming system transition as well as once a biodiversity-based FS is well-established. Research should analyse and highlight trade-offs, synergies or neutral relations between SE from field to landscape levels.

These two latter agriculture models are currently very marginal or do not really exist in most developed countries due to many lockins (Vanloqueren & Baret, 2009). Overall, it is important to bear in mind that organic agriculture, often presented as a promising pathway towards sustainable agriculture, can be present in the fifth and last different agriculture models. As the different agriculture models can and may exist in the same area, conditions under which they co-exist should also be clarified. More precisely, biophysical and socio-economic trade-offs, synergies or neutral co-existence between them at landscape and territory up to global levels have to be analysed. For example, it is necessary to clarify to what extent and under what conditions the presence of inputs-based FS in the landscape is compatible with the objectives of developing ES at the landscape level.

Conclusion

During the last decade, current research made some progress to better support the development of the two systems involving biological inputs-based FS. However, research activities presently dedicated to the development of biodiversity-based FS need to be strengthened. Our classification should help to better address the knowledge gaps, particularly regarding the development of locally integrated forms of agriculture based on diversified FS (integrated in local food systems and collective landscape management) (DeLonge et al., 2016; Levidow et al., 2014; Vanloqueren & Baret, 2009). Further progress in research strategy should address the challenge of a correct balance between researches on agroecology, bioeconomy and technology and, furthermore, should favour the integration of these three approaches. Most of all, the different models of our typology can be used for examining where funds are mainly allocated for research, training and development, identifying possible deviations from targets and informing the design of adapted agricultural policies and research agenda.

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Learning from organic farming: overcoming barriers to adopting agroecology

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Abstract: Certified organic production has existed for decades and many of the social challenges faced by organic farmers are also faced by farmers who are considering the philosophy of agroecology. Examining how organic farmers, who are easily identified by their certification, have overcome social barriers to conversion could shed light on how farmers may be motivated to adopt agroecological practices. The aim of this study was to identify whether social factors provide barriers to conversion and, if so, to identify strategies by which these barriers might be overcome. Interviews were conducted with 39 farmers of mixed and arable farms in the German (n=24) and French (n=15) speaking parts of Switzerland, which were analysed according to their content. The results suggest that attitudes towards the concept of organic production are often formed on the basis of quickly-formed impressions rather than considered deliberation. Furthermore, farmers perceive social pressure to focus on productivity, and organic farming is often perceived by non-organic farmers to be less productive. On the other hand, non-organic and organic farmers were found to have more similarities than differences in their goals and practices, with organic farmers reporting that conversion to organic had turned out to be less difficult than foreseen. These findings lead to several proposed courses of action for organisations wishing to promote organic farming practices; with most based around encouraging dialogue between conventional and organic farmers to counteract feelings of 'us-versus-them'.

Keywords: Conversion, organic farming, barriers, enablers, motivations

Introduction

Agroecological farming is a philosophy of agricultural practice (Wezel et al., 2009) rather than a particular type of agriculture, but shares many of the same principles as organic farming (Schulman, 2016). Organic farming has sustainability (and especially sustainable soil fertility) at farm level at its core, while agroecology considers the ecosystem services provided by farmland at the ecosystem level, including soil health, water quality, air quality, pest control, disease control and biodiversity (Bellon et al., 2011). A further difference is that organic farming has a requirement for certification if the produce is to be marketed as organically produced. Discussion of whether organic agriculture be considered to be agrocecology is commonly illustrated with examples of organic production that are clearly not agroecological, such as industrial scale organic operations that focus solely on maximising production rather than following an ecological ideology (Schulman, 2016). Organic farms in Switzerland however are typically small (average 24.5 hectares) mixed farms, and farmers are required to reserve a minimum of seven percent of their land for ecological compensation. Conversion to organic production in Switzerland can usually be considered to be a fundamental agreement with the principles of agroecology, so examining how Swiss farmers can overcome the social barriers to conversion to organic could inform strategies intended to ease some of the challenges of adopting agroecological practice.

Organic farming is financially supported by the Swiss Government, which pays organic producers a further ‘ecological’ direct payment in addition to the general direct payment (BfS, 2016) that is paid to (practically) all farmers in Switzerland, on condition that they provide proof of ecological performance. Sanders et al. (2011) conducted an economic evaluation and found that the income on organic farms was approximately 25% higher than on comparable conventional farms. If financial considerations were the deciding factor in whether to convert, we could expect financially motivated farmers to convert to organic in large numbers. This was indeed the case in Switzerland from the mid-90s during which the number of organic farms rose from 3300 (4.15% of all farms) in 1995 to 6400 (10.01% of all farms) in 2005. Although the proportion of organic farms has increased to 11.73% of all farms in Switzerland in 2015, the actual number of organic farms has decreased slightly to 6244 organic farms (BfS, 2016a). This leads to the conclusion that financial incentives alone are not sufficient to motivate farmers to convert to organic, which in turn suggests that barriers to conversion must exist. Actions to encourage organic cultivation practices on private farms require appropriately designed and effectively targeted incentives (Rodriguez et al., 2009). The means of motivation will be more successful in leading to the desired behaviour if incentives or directives are tailored to complement existing or intrinsic motivations and to removing barriers, which requires gaining an understanding of what motivates or hinders conversion to organic practices on farms.

Padel et al. (2009) described the first movers – or pioneers - in adopting the innovation that is organic farming as being primarily motivated by ideology and only weakly motivated to remain integrated in existing local social structures. Indeed, conversion to organic in the early years of organic farming often meant some degree of alienation from the conventional farming community (Padel et al., 2009). In their study of motivations for conversion to organic, Häfliger and Maurer (1996) found that the significant conversion to organic farming in the mid to late ‘90s mostly consisted of farmers who were primarily economically motivated but who also wished to maintain their standing and acceptance in their community. A further influence on decisions are the attitudes held within the farmer’s own family, which can be positive or negative towards the concept of organic cultivation (Goy, 2007). Ferjani, et al. (2010) on the other hand reported that the attitudes held by neighbours and family were only a minor influence on the decisions made by farmers, with the exception of the group that they called ‘optimisers’, for whom social acceptance was important. An extension of such consideration of what other farmers in the community may think is the reluctance to enter situations in which conflict with neighbours may occur. Several well publicised conflicts between organic farmers and their neighbours create an understandable degree of apprehension for those considering conversion (Madelrieux & Alavoine-Mornas, 2012).

Further barriers to conversion to organic farming that can be identified in the literature relate to technical difficulties in cultivation and the knowledge and learning required. Farmers considering conversion were also concerned with the extra work burden that was perceived to be associated with organic farming (Ferjani, et al., 2010; Goy, 2008). Furthermore, the difficulty of cultivation of lucrative crops, such as sugarbeet, is a barrier for many farmers considering conversion (Schramek & Schnaut, 2004). Studies by Khaledi et al. (2010), and Padel et al. (2009) however, found that conversion barriers cannot be removed by simply finding solutions to economic and technical problems. Khaledi et al. (2010) reported that the risk of conversion was considered by many farmers to be too high, although Schneider (2001) found that the risks were generally overestimated.

A reasonable conclusion is that the relationship between farmers' motivations and behaviour is complex and our understanding is inadequate. Quinn and Burbach (2008) suggest that changes to more sustainable behaviour are the result of a complex relationship between attitudes, reasoning, intrinsic process motivation, goal internalisation and internal self-concept. Burton and Paragahawewa (2011) argue that a non-economic form of capital is the status and prestige within farming communities generated by particular behaviours, which can be an effective motivation in the decision as to whether or not to convert to organic cultivation. Similarly, Khaledi et al. (2010), and Padel et al. (2009) identified that social norms, the social situation on the farm, personal values, and attitudes held by the farming family are likely to be dominant decision criteria. The aim of this study is to identify barriers for Swiss farmers to convert to organic farming and to learn how these barriers have been overcome by farming families that have successfully converted. These lessons could ease the process of farmers converting in the future, thus making the transition easier. Furthermore, the similarities with the social challenges facing farmers who operate under the principles of agroecology suggest that the lessons might also be transferable to that context.

Material and Methods

A total of 24 semi-structured interviews with farmers from the German speaking part of Switzerland, and 15 interviews with farmers from the French speaking part of Switzerland were conducted. Half of the interview partners were organic farmers; meaning they had converted to organic farming and been certified as organic producers by BioSuisse, which is the primary organic certifying body in Switzerland. The remaining farmers were certified by an organisation known as IP Suisse, which is an association (with over 20 000 members, which is 38% of all farms) of farmers who produce using environmentally and animal friendly production methods; including being GM free and with minimal use of synthetic pesticides. IP farmers were selected for inclusion in this study because they are readily identified and because their choosing IP membership indicated a degree of openness to ecological concepts. Individual farms were selected to represent a wide range of farm sizes (from 6.5 to 98 hectares); a wide range of experience with the respective farming system (from 0 to 38 years); and both the French and German language regions. A further selection criterion was that all farms should produce some crops. The interviews were transcribed and their content was coded.

Analysis

An encompassing theory that offers some explanation of how the relationship between attitudes, social norms and perceived limitations can be reconciled is needed. Examination of how individuals, in this case farmers, can be motivated to engage in a behaviour that has been externally evaluated in a political process as being desirable, is essentially an examination of why they choose to do so or not to do so. There is an underlying rational process in human decision-making, and decisions to adopt a particular behaviour are made to maximise the individual's total utility (Friedman, 1990). The theory of planned behaviour explains behavioural intention as a combination of the attitudes and subjective norms held by an individual that are constrained by the individual's confidence in their ability to implement the behaviour and produce the desired outcome (Ajzen, 1991). The theory is among the most powerful and predictive models for explaining human behaviour (Koger & Du Nann Winter, 2010). The constructs identified in the interviews were classified according to Ajzen's (1991) theory of planned behaviour, which allowed concrete recommendations for ways to reduce barriers to conversion to be proposed. For brevity, we refer to the participating farmers simply as 'farmers' throughout the presentation of results and discussion in this paper. Direct (translated) citations from farmers are shown in italics followed by an identification of the farm type; either Bio or IP.

Results

Subjective norms

A key social factor that acts as a barrier to conversion is a perceived negative attitude towards organic agriculture by other members of the family. Often farmers feared the reactions of parents; especially that of the father from whom they had inherited the farm, and who usually continues to live on the farm. If the young farmer wants to realise his or her own ideas, there is a high potential for tension to be created with their predecessor. However, many farmers found that the predecessors learned to accept new management forms after some time; and after they had seen that the new production method was successful. A positive attitude and generous support from the life partner, who was in most cases the female partner of a male farmer, were highlighted as particularly important for change. In several cases, the life partner provided the drive for change as they were concerned about the use of pesticides in the vicinity of their own children. In the case of the French speaking farmers, their partners were usually employed off-farm, with limited presence in the general decision making, and so had less influence on the farming decisions

In addition to the acceptance by family, acceptance and recognition by other farmers is an important motivation. Several farmers pointed out that there was a need for mutual respect among farmers, regardless of the form of production. Organic farmers expect respect and tolerance from non-organic colleagues; as well as understanding if things go wrong "*I had a good relationship with my neighbours and colleagues, and they knew me when I was an IP farmer, and I'm still valued now that I'm an organic farmer. That's a big honour*" (Bio). Many of the interviewed farmers continued with collaborative arrangements with neighbouring non-organic farmers after conversion, which they interpreted as a sign of acceptance: "*We still share machinery and still have a good relationship. There's mutual respect*" (Bio). Neighbouring farmers show a certain tolerance to errors of farmers who have recently converted. Mistakes and failures are considered rather as an opportunity for learning, and every farmer, including IP farmers, had a story of an expensive mistake from their early farming days. However, technical problems, such as the use of copper based fungicides in organic agriculture, do need to be solved and ongoing efforts to solve technical problems are viewed as being central. On the other hand, successes are also noted and can contribute to more positive attitudes towards organic cultivation: "*I've been complimented by other farmers who've said "Hey, you can do so much, and make good products, also without chemicals"*" (Bio).

However, mutual respect was not always present. In some cases, the decision not to apply synthetic chemical sprays was the trigger for conflicts with neighbours: "*then the organic farmer came and planted potatoes, and they had leaf blight and did nothing. That was terrible…I had to wash ours with fungicide so that I could get by*" (IP). On the other hand, IP farmers are not always respected by the organic farmers: "*I've never personally spoken badly of non-organic farmers, or brought them down, but I know others do*" (Bio). Soil protection was nominated by organic farmers as a reason for conversion, and non-organic farmers are sometimes seen to have a cavalier attitude to synthetic inputs: "*They spread the slug pellets without actually checking whether they have slugs*" (Bio). This position of disrespect is counterproductive, since it can lead to alienation from both sides. A non-organic farmer who does not feel respected by the organic farmers may turn away from them and be even more difficult to reach.

The interviewed organic farmers reported that they felt closely observed by neighbouring farmers immediately following conversion, but that the level of observation returned to the "normal" level after a certain time. Organic farmers feel that they are judged by the same criteria as other farmers: quality and yield. Accordingly, farmers who allow weeds to get out of hand or exhibit other signs of poor management, are not very highly regarded; regardless of the form of production they use. However, organic farmers are often seen as representatives of their form of production, and more so than is the case with IP farmers. Some organic growers have tried especially hard to keep fields free of weeds to prove to their neighbours that one can have orderly fields in organic farming. Thus they hoped to obtain recognition in the social environment. Despite the clearly expressed wish for the acceptance by their peers, farmers still deny that it is important to them: "*if you always listen to what the others want, you might not be on the right path*" (IP).

Attitudes

Many farmers reported that they first needed to make a change to organic in their own minds. To accompany the process of "mental conversion", it is important that conversion to organic agriculture means that the farmer remains within their individual value system. On a general level, this is not a particularly difficult step to make because a large overlap was found between the identities of organic and the IP farmers. They all see themselves as sustainable producers, they all care about soil conservation, and they all see themselves as independent decision makers on their farms.

Both organic and IP farmers see themselves as producers, but the IP farmers sometimes see organic farmers as living from direct payments rather than production. Non-organic farming is considered to be the 'normal' way of production: "*the attitudes towards the productivity they want, and it's just still based around having clean fields, but it's all about production and yield, yield, yield*" (Bio). An organic farmer reiterated, however, that organic farming is also production oriented and that "*direct payments make up a much smaller part than the product sales, so organic farming is also productive agriculture*" (Bio). The IP farmers perceive two types of organic farmers: productive farmers and those who milk the direct payment system: "*If I can't produce, and I would say this very provocatively, I might as well go organic*"(IP). Dishonesty and living from the system rather than producing is not seen solely as the domain of organic farmers, but there are perceived to be fewer dishonest farmers using non organic production systems: "*There are some*"(IP). The IP farmers have little time for those they consider to be dishonest by living from subsidies and having little interest in production, but are also critical of the system in which this is tolerated: "*One can do that in organic*" (IP).

The protection of resources, and especially the soil, was reported by all of the farmers as being extremely important. However, reduced use of synthetic additives is also commonly seen as a means of soil protection by the IP farmers: "*it's important to use fewer chemicals*" (IP). The wish to remain productive however remains, and the goal to produce sustainably appears to be universal: "*We want to keep the arable land and produce food cleverly*" (IP). Contrary to the opinions of some organic farmers, IP farmers also doubt the long term wisdom of synthetic inputs: "*There's the question of whether the chemicals will really degrade as they say, and also what effects they have on the soil life*" (IP). Both groups of farmers have a preference for methods that are environmentally friendly and are better for the soil.

One obstacle for some farmers was a perceived loss of independence, which they expected in the course of conversion to organic farming. They fear being limited by a wide range of complex rules and regulations. However, organic farmers evaluated their self-determination to be higher than before the changeover, and see this as an important positive factor: "*Before we became organic, a company used to come and do all our spraying. We didn't have much to do with it. They just sent us a bill and we paid it*" (Bio). After conversion, farmers reported making the decisions themselves and feel that this stronger power of decision-making gives them a stronger connection to the land. Organic production was seen to give an overall gain of self-determination, and especially independence from major players in the agricultural market, such as suppliers or distributors of synthetic inputs. All of the farmers value their independence and freedom to make decisions, and are unhappy when this freedom is restricted, but every farmer has some restrictions on what they can do if they are to receive direct payments of subsidies.

Conclusions

A barrier to conversion that was related to technical issues was the lack of awareness among IP farmers of organic solutions to problems. Non organic farmers are free to attend 'organic' events, and information is available to them, but this knowledge transfer could be enhanced if solutions that are found in the organic world were actively and deliberately publicised to conventional farmers. Farmers don't use expensive synthetic inputs because they feel the need to spend money, but rather because they don't see viable alternatives. If they are made aware of such alternatives, and implement these alternatives, the step to conversion becomes smaller and more likely. The process of publicising solutions will encourage contact between organic and non-organic farmers, which may enable farmers to feel part of the same network and reduce an us-versus-them dynamic. A further result of the publicising of solutions is that organic farming may be perceived to be production oriented and to be facing the same problems as conventional farming. The finding that there is no recipe as such and that each farmer must find their own solutions that work for their own farm means that the conversion to organic is perceived to be uncertain. This uncertainty persists despite the extensive and highly regarded advice that is readily available to farmers. Better networking opportunities for organic farmers, and also between organic and non-organic farmers would enable exchanges and reduce the uncertainty of conversion. This finding suggests that social measures can contribute to encouraging conversion.

In areas in which the concentration of organic farmers is smaller, such as the French speaking part of Switzerland, organic farmers look for alternative means for exchange with their peers, such as online forums and websites. Other means of encouraging exchange among colleagues could be the hosting of contact events: with co-hosting between organic and non-organic farming associations. Such events could have the effect of strengthening the reputation of organic farmers as producers. Organic farmers expect to be respected by non-organic farmers and vice versa, and such respect can be encouraged by creating spaces for dialogue between the farmer groups. The finding that all farmers have more in common than they have differences suggests that farmers attending such events will be able to easily find common ground. Such events could consist of organised demonstrations of successful organic farming innovations. Demonstrating a production orientation, elaborating on experiences, and engaging in dialogue with non-organic farmers could contribute to a more open attitude by non-organic farmers.

A further measure that could contribute to changing attitudes could be the introduction of courses in the organic cultivation of gardens with a concentration on farm gardens or husbandry of small animals. In the Swiss farming system, cultivation of the house garden and care of the small animals usually lies with women, who it is known can have a strong influence on the decision to convert. Participation in such courses would have the dual role of demonstration of the effectiveness of organic cultivation techniques and recruiting the participant as a proponent of organic. A further means of demonstrating the effectiveness of organic cultivation techniques but on a larger scale could be the initiation of farm visits. In addition to their demonstration role, such visits would also encourage dialogue between organic and non-organic farmers, and thereby contribute to farmers finding common ground. Non-organic farmers would learn that most organic farmers tended to overestimate the difficulty of conversion and of running a farm organically.

The result of the project is a deeper understanding of the social and personal factors that influence the conversion to organic farming, as well as how barriers have been overcome by farming families. A variety of social and personal factors were identified and most, if not all, can be considered to be human characteristics; desire for acceptance by peers and family, desire to succeed, and desire for self-determination. These results suggest the value of implementing a range of concrete actions that can ease the decision process and enable conversion within the farmers' minds. The common theme throughout the recommendations is to facilitate communication between organic and non-organic farmers so that their similarities, rather than their differences, are in the foreground. For example, informal events and platforms for the exchange of information between organic farmers and interested non-organic farmers could motivate curious farmers to take the second step of seeking official advice. The boundary between agroecological and conventional production systems is described in the introduction to this workshop as one of tension at an ideological level and some synergy at the scientific and applied level. This study found similar tensions at the boundaries (sometimes literally) between organic and IP production in Switzerland and a range of synergies at the applied level. We make no claim that organic farming is synonymous with agroecological farming, but we do suggest that measures for bridging the gap between organic and non-organic farmers in Switzerland may also ease the transition to agroecological farming practices for conventional farmers elsewhere.

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The re-innovation of mixed cropping – who's interested?

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Extended Abstract

Introduction

Mixed cropping (MC), the growing of two or more main crops in one field that coexist for a time, can help to design a more sustainable agricultural land use, due to a variety of ecological benefits relative to mono-stands. Specifically, we look at the industrialised alley cropping approach for cereal and grain legume mixtures which reduces synthetic fertilisation needs, improves biological pest management, increases drought resistance and can limit the risk for lodging (a full list of ecological benefits and references will be published with the full paper). MC goes hand in hand with benefits for agrodiversity and the associated biodiversity (Malézieux et al., 2009).

Despite its ecological benefits, there is a lack of political support or consideration of MC, due to a lack of interest among stakeholders within the agricultural sector. Such interest can spill over among farmers, agribusinesses and researchers, but today's interest in MC is restricted to the assessment of ecological benefits. Overall knowledge of implementations is scarce among farmers (in 2014 about 0.007% of cropping land is distributed to MC in Germany) and among researchers (Duc et al., 2015). All research and development and agriculture machineries evolve around monocultures. Economically, MC does not receive financial support like pure legume stands within the EU and therefore needs to compete with pure cereal stands. While grain productivity of MC is higher than in comparable mono stands in low input systems (Brooker et al., 2015; Duc et al., 2015), research is not conclusive in high input systems. Additionally many stakeholders believe there are substantial technical barriers to hinder the industrialisation of MC.

To learn more about the lack of interest among stakeholders that hinders the development of this agroecological production system, we profile who is interested in the diffusion of MC in relation to potential promoters and antagonists. A potential promoter is a critical perception of sustainability issues, in case MC is considered suitable to ease these issues. Such issues may be the intensive use of synthetic fertilisers or the steadily declining biodiversity in agricultural systems. In contrast a critical perception of different technical barriers, involved in efficient MC implementation, might reduce interest. Recalling that MC is closely linked to the ideas of agroecological production methods, another barrier can be an actor's conventional paradigm rather than an alternative/agroecological paradigm. It is probable that ideas based in one paradigm are somewhat difficult to endorse by supporters of the opposing one. MC might need to span the paradigm gap in order to encourage adoption.

Methodology
Looking into innovation diffusion, Beal and Bohlen (1957) have theorised the adoption process of farmers. Crucial steps on the ladder to adoption are the interest stage, which reflects an eagerness to reach for new information, and trial willingness, which represents a small scale experimental use in order to assess and prepare full adoption. The concept of trial willingness is only applicable to farmers. Other agriculture value chain actors may only indicate their interest in MC. Nevertheless such actors have been found to influence diffusion.

We undertook a survey of agricultural students, predominantly agribusiness students, at a German University. Such students do commonly proceed to work in agriculture value chains after their studies and are highly involved in agricultural topics. To improve the measurement of Beal and Bohlen's (1957) adoption stages, we operationalise interest and trial willingness, not by attitude, but by behavioural measures with real-life implications: (1) to provide an email to receive more detailed information on MC; (2) to participate in a 1.5-hour information event on MC; and (3) the students with a farming background have additionally been asked to trial MC on a minimum of 1 ha of land. An incentive of 250€ was offered for field trials.

An applicable multiple imputation method was used to avoid the dropping of meaningful observations. Next three logit models regressed a fixed set of independent variables upon interest and trial willingness. The model's results were graphically illustrated in consideration of standards in reporting statistics.

Results and Discussion
Counterintuitively, the results did not imply that strong agroecological attitudes based on the alternative paradigm lead to behavioural interest or trial willingness in MC. During the MC-information event the students have proposed an attitude-behaviour-gap, as some feel ecological attitudes are increasingly common, but are not necessarily acted upon. Students with conventional attitudes can also enjoy the efficiency gains related to MC. Therefore marketing efforts need not be limited to groups with ecological focus like the organic community.

The interest in MC was also positively related to a strong concern for biodiversity, extensive soy imports and synthetic fertiliser use. The media life cycle of these issues will likely affect the future interest in MC. However trialling was not significantly related to such issues, rather a critical perception of barriers to marketing crop mixes stands out among other technical challenges to decrease the willingness to undertake trials. The additional costs of harvesting mixed crops were not quantified, due to the lack of economic research, but can be of particular value in order to increase transparency in MC adoption decisions.

Conclusion
This study provides a socio-economic analysis of an under-researched production method that can help to create a pathway for a more sustainable agriculture production. Altogether, the findings of the study present a snapshot of interest among today's agriculture students and will help agribusinesses to profile early adopters for MC-related technologies. Uniquely, the study introduces novel behavioural measures to interest and trial willingness within adoption processes which assist in an accurate identification of the concepts.

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Increasing searches for autonomy among French farmers: a starting point for agroecology?

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Abstract: In Western European agriculture, an increasing number of conventional farmers are actively augmenting the autonomy of their farm enterprises. They do so, amongst other things, through decreasing the external inputs, whilst simultaneously improving the use of internal resources. Thus, low external input farming systems emerge that increasingly enhance ecological processes. Simultaneously, the farmers involved may maintain key features of their entrepreneurial mode of farming. In this context, the network of French farm machinery cooperatives has witnessed a movement of collective innovation experienced by farmer members to become more autonomous. The present paper aims at better understanding this phenomenon visible within some French farm machinery co-ops. Our methodology is based on an exploratory survey of 15 machinery co-ops and a range of six in-depth case studies among them. Our work combines a farming system and a sociological approach. Most of the studied farmers mainly seek to become more autonomous from markets, notably from input markets. A proportion of them also claim to gain autonomy from advisory services and regulatory institutions. The current price volatility context appears as one of several decisive factors for many of the farmers interviewed to seek the means to become more autonomous. The collective organisation provided by the socio-technical network of farmers' arrangements associated with their machinery co-op, has allowed them to benefit from favourable conditions under which to undertake the new practices. We conclude by suggesting some lessons from these experiences to strengthen local networks of farmers' sharing arrangements as a conducive arena for agroecological transition.

Keywords: Farm machinery cooperative, autonomy, agroecology, farming system, farmers' collective, technical change, transition, agricultural cooperatives

Introduction

In France, the current socioeconomic and ecological context (rising costs of animal feed, price volatility, droughts, new public regulations and private specifications, etc.) is increasingly leading farmers to innovate and develop their autonomy. To do so, conventional farmers are implementing new practices such as self-provisioning strategies, legumes integration, no-tillage, etc. Different elements out of a broader agroecological strategy are therefore being implemented (and further developed) by French farmers. Although they do so without referring to the concept of agroecology, they develop low-input and more diversified farming systems by making better use of the ecological functionalities of the agroecosystem. Simultaneously, they maintain key features of the conventional mode of farming such as high yields, automation and zero grazing.

The French National Federation of farm machinery cooperatives is particularly affected by this phenomenon. There are 11,000 farm machinery cooperatives in France, comprising one third of all French farmers. The leaders of this network have recently observed a movement of collective innovation experienced by farmers within their machinery co-ops, conducive to developing their autonomy.

This paper aims at appraising if this collective movement might be supported and strengthened to allow a broader agroecological transition in agricultural production. To do so, it will examine the main results of an action research programme which seeks to understand the phenomenon of collective innovation in the machinery co-op network which makes feasible the increasing searches for autonomy among conventional farmers. Who are these farmers who newly search for autonomy? How do they manage to reduce external input use whilst aiming to maintain a high level of production?

The first part of the article presents a brief literature review regarding the paradoxical interaction between farmers' searches for autonomy and agroecology. In the second part we describe the functioning of the French farm machinery co-ops, before explaining our methodology. In the third part we examine farmers' paths to develop their autonomy, as well as the contribution of the collective organisation to facilitate the change process. We then discuss the potential of the machinery co-ops for agroecological innovation.

Autonomy: a paradoxical interaction with agroecology

Before developing our examination of autonomy and agroecology, we explain on which definition of the latter we base our present work. Following Francis et al. (2003), we consider the agroecology as the development and application of ecological theory to the entire food systems, encompassing ecological, economic and social dimensions. From this broad approach we focus in particular on the farm segment, including the territorial and landscape levels. At these levels we examine the adaptations of the agricultural practices made individually and collectively by the farmers to design diversified farming systems tailored to local conditions which seek to enhance ecological processes and interactions, and to improve the sustainability of the local agroecosystems (Wezel et al., 2015; Nicholls et al., 2016).

Autonomy as a value

The literature review reveals that the concept of autonomy incorporates a multiplicity of interpretations and connotations, especially due to the national and ideological background. Emery (2015) highlights that the British political and social theorist Lukes has presented the autonomy as one of the three faces of liberty and maintained that it is achieved when an individual ''*subjects the pressures and norms with which he is confronted to conscious and critical evaluation, and forms intentions and reaches practical decisions as the result of independent and rational reflection''* (2006 [1973], p. 55). However, words of farmers throughout many parts of the world reveal that autonomy is often synonymous with independence and individualism, owing to the work of the dominant ideology, which is currently neoliberal ideology, which makes them appear so (Emery, 2015; Stok et al., 2014).

Moreover, Lukes highlights that historically the concept of individualism had distinct connotations according to the national contexts. Appearing during the 19th century in France, it still carries in this country a pejorative connotation, suggesting the dissolution of the social system. In England it had become synonymous with minimal state intervention and opposition to socialism. In the United States it had become a usual word to qualify the economic liberalism, the limits of the government action and the individual freedom (2006 [1973]). This explains the multiple interpretations of the autonomy. For instance, Emery (2015) shows that for English farmers, autonomy and independence are often conflated with individualistic premises. He argues that this limits their involvement in collective action and thus increases their dependency on the structural and economic forces that impose real limitations on their work and lives.

Autonomy as a guiding principle

In contrast with the autonomy considered as a value, some authors show how farmers may also value autonomy as a guiding principle or as a tool of navigation to manage the farm (Stock & Forney, 2014; Ploeg, 2008). From this approach, Forney (2016) calls for promoting autonomy to open new paths to make agriculture more sustainable.

Actually, various authors have highlighted how the development of organic and alternative farming has been interlinked with farmers' striving to develop their autonomy and agency (Altieri & Toledo, 2011; Lucas & Sabourin, 2011; Coolsaeth, 2015). For instance, in France, the first certification standard for organic farming was developed in 1963 by a commercial organic fertiliser company founded by two agronomists, Lemaire and Boucher. They proposed a contract farming approach which offered a production method based on two external inputs - a specific wheat seed and a calcified algae - whose use allowed contracting farmers to sell their products by using the “Lemaire & Boucher” brand. A new association of producers and consumers, “Nature & Progrès”, emerged in 1964, partly as a critical approach toward this trade dimension. They also questioned the external inputs dependency induced by agricultural modernisation. They created the first French certification scheme for organic farming in 1970, including autonomy as an ordering principle (Nicourt, 2015). In the UK context, Morgan and Murdoch (2000) have assessed that organic farmers, compared with conventional farmers, are able to exercise more autonomy and control both in relation to means of production on their farm and to actors of the food chain.

Recent research has revealed how French organic farmers make compromises to deal with the autonomy principle. Nicourt (2013a) shows that there are only a few organic pork breeders in France who have to face a context of trade vulnerability. Some of them choose to develop direct selling, sometimes with on-farm processing, which may create competition between their farming activities. As a result, the development of trade tasks often occurs to the detriment of crop and livestock production, which may be delegated to contractors, paid employees or to other farmers. Hellec and Blouet (2012) describe how new organic dairy companies have recently emerged and organised farmers' conversion to organic farming. Their case study from eastern France shows that a dairy company wants to ensure its volume of business and thus selects farmers with high productivity levels. These buy fodder from off-farm by using the exemptions allowed by the organic regulations.

Demeulenaere and Bonneuil (2010) and Goulet (2010) have studied two alternative agriculture movements: network of peasant seeds and communities of practice organised around no-tillage and direct seeding techniques. They observed a similar desire for farmers to manage their activities within their own means (i.e. without the support of third parties). Even if both movements seem to be distinct regarding the production systems practised and the socio-political orientations, developing autonomy regarding advisory institutions and input markets is a common aim and they both rely on networking.

Recent work has also shown an increasing wish among conventional farmers to develop their autonomy: the context of economic and ecological uncertainty is currently strengthening and renewing farmers' desire for this across the board (Darnhoffer, 2010; Ploeg, 2008; Schneider & Niederle, 2010). Ploeg (2008: pp. 152-154) identified six mechanisms through which farmers try to become more autonomous:

1) To better face the input and commodity markets, which tend to increasingly operate in oligopolistic ways, many farmers diversify their outputs in a range of ways, sometimes whilst simultaneously creating new market outlets;
2) To better face the input markets, farmers tend to develop low-input or more cost effective modes of farming. Thanks to these strategies, farmers may structure the relations with markets in ways that allow for autonomy;
3) Farmers tend to increasingly base the process of production upon their own resources, especially by re-grounding agriculture upon nature. It implies e.g. the revitalisation of soil biology, or the breeding of animals that can be fed with local resources;
4) Increasing the technical efficiency of the production processes as a long-term strategy allows farmers to attain a higher production level with the same set of resources. This results from farmers' careful observation, small on-farm experiments and progressive improvement of the internal resources used and their potential synergies;
5) Pluri-activity, when it aims, among others at strengthening the total income and at scattering the economic risks, may be considered as a strategy to develop autonomy, for instance in relation to the bank credit;
6) Finally, local forms of cooperation among farmers contribute to delinking farmers from dependency on financial and industrial capital.

These mechanisms are not mutually exclusive and may form a multi-faceted and articulated strategy to develop farmers' autonomy.

Autonomy at the collective level

Some social scientists demonstrate that opposition may occur between autonomy and sustainable farming. As Emery (2015) observes, the value in independence has often been used to explain the lack of cooperation among farmers, especially for collaborative agri-environmental schemes. This often leads policy makers to design these approaches through individual contracts with farmers. Doing so, they limit the possibility for farmers to interact and benefit from sharing of experiences to put the schemes into action. They also reduce the potential of landscape based approaches.

Farmers' searches for autonomy may face difficulties due to “path dependency” resulting from the dominant socio-technical regime that locks-in possibilities for agroecological transition (Vanloqueren & Baret, 2009). The collective organisation of the farmers sometimes leads to efficient ways to overstep the sociotechnical lock-ins, by setting in niches of innovation, allowing novelty production and knowledge creation (Wiskerke & Ploeg, 2004; Stock et al., 2014).

To conclude, farmers' searches for autonomy appear as a multi-faceted phenomenon, which has contributed to organic and agroecological farming development. Autonomy aimed at reducing the dependencies on markets, imposed top-down regulations and dominant technological regimes appears as a robust tool for agroecology, especially whilst articulating a cooperative approach between farmers. Thus, examining the potential of farm machinery co-ops for agroecological transition appears to be a relevant issue.

Methods and Materials

The machinery co-op: a socio-technical network of farmers' sharing arrangements

In France, the agricultural policies of 1960 and 1962 have framed the modernisation process, by strongly valuing farmers' collective organisation and action. As a result, farmers' organisations have become driving forces to implement a family productivist farm model in France (Nicolas, 1988; Nicourt, 2013b). This explains the widespread machinery co-op network, which currently comprises more than 11,000 units throughout the French regions.

On average, a French machinery co-op includes 25 farmers, with the smallest composed of 4 farmers which is the authorised minimum membership. It is based on the commitment contract. For each member, the contract implies the commitment to use a minimum amount of one or several pieces of equipment for a multi-year period.

To share machinery in the optimal way, machinery co-op's members often organise machinery-sharing arrangements to avoid the constraints induced by the sharing situation. For instance, to avoid competition among members of the machinery co-op when specific climatic conditions are needed to successfully perform some operations. Farmers also organise labour-sharing arrangements such as the following: joint organisation of tasks, delegating to common paid employees, mutual aid, etc. The machinery co-ops network promotes the organisation of labour banks between farmers to facilitate labour exchanges between peers.

The habit of sharing equipment and working together may create a trust level that triggers other kinds of machinery-sharing arrangements between some members (often in a bilateral way), such as co-ownership. Some other resources-sharing arrangements may emerge or other kinds or collective arrangements, such as coordinated purchases pools (Lucas et al., 2014).

This is why the functioning of a machinery co-op cannot be understood without considering the whole socio-technical network of farmers' sharing arrangements that it is associated with Dodier (1995).

Methodology

Two theoretical frameworks from development studies and innovation sociology inspire our analysis. Work performed by the Dutch sociologist Ploeg (2008) regarding farmers' autonomy provided us with an analytical framework to examine farmers' strategies for developing their autonomy. Works of the French sociologist Darré (1996) deal with the knowledge development issue, generated by social interactions between farmers. According to Darré, a collective process occurs in dialogues between peers at the local level. In addition, individual farmers may simultaneously belong to other networks of dialogues, where they have access to other sources of knowledge, representations and narratives. This “multi-membership”, as Darré calls it, is a source of novelties. These works have allowed us to focus on the experience of the farmers studied regarding the dialogical processes with their peers, which underpins the change process.

Our methodology is based on two processes:

1) We ran an exploratory survey of 15 farm machinery co-ops, covering different geographical contexts and farming systems. They were identified with the help of advisors of the machinery co-op network. In each selected co-op, some of the members had been engaged in sustainable practices requiring some pieces of the machinery co-op's equipment. Data collection took place through semi-structured interviews with one or several leaders of each co-op. We focused on the history and activities of the machinery co-op, especially in relation to specific machinery allowing development of sustainable practices. The exploratory survey allowed us to identify the search for autonomy as a common motivation among the different groups visited.

2) We carried out in-depth research on six of these co-ops, whose members are engaged in legume introduction or no-tillage practices on their farms. Indeed, data of the national network of machinery co-ops currently reveal increasing investment in specific equipment regarding these practices. Thirty-six semi-structured individual interviews were conducted with farmer members of the six co-ops. The results of the interviews were recorded. Firstly they were analysed via a discourse analysis to identify the conceptions regarding autonomy. Secondly, the analysis has allowed us to draw the socio-technical determinants of farmers' strategies.

Paths and practices for autonomy

A whole series of circumstances has occurred over about fifteen years in France that has triggered initiatives from farmers to decrease the use of external inputs. Most of the interviewed farmers allude to the notion of autonomy to explain their new practices.

Reducing external inputs

Most of the farmers interviewed explain how they seek to decrease external inputs to reduce their costs, especially because of the current price volatility context that has set in since 2007.

Some of the interviewees seek to produce more protein and legume crops and grass on farms to feed their animals. These ones may provide origin-based livestock products markets or be involved in direct selling to consumers. This new trend has emerged after important campaigns organised by environmental NGO (Greenpeace, WWF, etc.) during the 2000s against GMO soybean imported by the European livestock sector (Escobar, 2014). Moreover, one group of farmers were encouraged by their agricultural marketing cooperative to use less external inputs for an environmental product differentiation strategy.

Most of the interviewees have introduced legume through winter cover crops, in response to the various agri-environmental schemes requiring the soil to be covered during winter.

Farmers allude to the aim of developing their autonomy when they explain the integration of these practices, allowing them to reduce external inputs and to improve internal resources and potentialities. This reveals that the interviewees choose to face the external prescriptions or pressures, such as price volatility, by actions that may contribute to strengthening their autonomy, especially by reducing their sensitivity to market fluctuations.

Mastering the farming system

Most of the farmers who were interviewed highlighted their wish to better master the technical processes whilst explaining their initiatives to develop autonomy.

Firstly, some of them describe their difficulty in accessing some external inputs. For instance, to introduce legumes, input suppliers do not always offer the right diversity of seeds at the right moment with a good price. To face this difficulty, many of the interviewees have decided to organise on-farm seed production. Another example: farmers who have to buy external fodder explain they have to face irregular quality problems. They experience the fodder market as a surplus market, easily affected by climate variations, which does not provide a constant and homogeneous fodder quality. That is why they seek to improve their on-farm fodder production by developing means to limit the losses. They also make the most of winter cover crops to produce additional fodder.

Secondly, most of the arable and mixed crop-livestock farmers experience increasing "agronomic deadlocks" because of short rotations, loss of organic matter and over-tillage. This explains changes such as no-tillage, new crop integration, winter cover crop development with legume introduction, and strengthening of crop/livestock interfaces.

Thirdly, some of the interviewees claim to be more autonomous regarding advisory services. For instance, they have chosen not to externalise administrative tasks such as accounting. This allows them to better know and master their own situations and have the means to properly guide their decision making. They also seek to avoid working with agricultural advisors who are simultaneously input salesmen, or they confront their advice with other sources of knowledge. Some of them have experienced difficulties with gaining access to relevant information in relation to their new practices (especially about legumes cultivation) from advisory services.

Finally, the price volatility that has occurred since 2007 often appears in the farmers' narratives as the final straw. This is on top of the other disappointments regarding input markets and advisory services, and has become a triggering factor for farmers to organise the adequate means to face them. In this way, farmers try to get their farming practices away from input markets and dominant socio-technical institutions.

Progressing towards more sustainable practices

The on-farm change process is strongly based on the determination and the resources of the farmers rather than on mobilisation of external techniques or inputs. Some of the farmers express the satisfaction they get from seeing the successful results of their own work and creativity. This encourages them to undertake new initiatives. This appears as a self-propelling dimension of autonomy development.

The current development of agri-environmental state policies and schemes may validate farmers to engage in reducing external inputs. Moreover, as reducing external inputs may be a way to make agriculture more environment-friendly, some of them want to meet the current general socio-political expectations. This does not appear as the starting motivation, but much more as an additional convincing factor. Indeed, the narratives of the interviewees reveal the paramount technical and productive norms and values in relation to their professional identification.

Most of the new practices, such as legume introduction, no-tillage and winter cover crops, are considered to contribute to climate mitigation by expert assessment (Pellerin et al., 2013). Moreover, some of the interviewees, especially those engaged for more than ten years in a change process to develop their autonomy, nowadays achieve a low level of external inputs, even to the extent of converting to organic farming.

The collective organisation to develop autonomy at the farm level

The network of arrangements associated with the farm machinery cooperatives make the practical integration of new practices feasible at farm level. Over the long term, farmers manage to develop the autonomy of the farming system that had a prior high level of external inputs and a current high level of productivity, thanks to the collective organisation.

The logistics challenge

The new practices to develop farmers' autonomy imply some backward moves with regard to two entrepreneurial farming trends: specialisation and externalisation. This has consequences for logistics. Crops and production specialisation allows management of the farm with a restricted set of equipment, i.e. machinery that is specific to a few crops or products. The use of external inputs may be considered as an externalisation process of the needed resource production. That is why developing self-provisioning or diversifying by introducing a new crop may imply new logistical needs, such as processing equipment, storage infrastructures, adapted machinery, etc.

Thus, dealing with a wide set of adjustable equipment to be able to diversify, to develop self-provisioning and/or to better ground the farming practices on their specific ecological conditions, becomes a substantial challenge for farmers. That is why the farm machinery co-ops are a significant asset in facing this logistical challenge by reducing equipment costs owing to the shared investment. Moreover, farmer members with mechanical skills contribute to developing tailored technological solutions, even self-built or self-designed equipment. In doing so, farmers seek to strengthen the “multifunctionality” of each piece of equipment.

Better improvement and access to strategic resources

Some resource-sharing arrangements are organised from the socio-technical network associated with the machinery co-op organisation. They facilitate some collective self-provisioning strategies to reduce external inputs and to better access strategic resources which are not well supplied through markets.

Seed-sharing is organised between farmers interviewed to avoid individual farmers having to multiply a wide set of the required seeds. The talks to collectively organise the multiplication work often emerge between farmers already associated through machinery- or labour-sharing arrangements, as well as through study groups.

Resource-exchange arrangements are sometimes organised between arable and livestock farmers to make the most of synergies between crops and livestock to better manage access to organic manure. Farmers of one of the studied machinery co-ops have organised an innovative arrangement about cover crops. Two sheep farmers arrange with neighbouring arable farmers to organise the grazing of cover crops by sheep. This allows the provision of organic manure to the soil during winter. In addition, the grazing of cover crops is an interesting way to reduce herbicide applications.

The role of the technical dialogues

The socio-technical network associated with the machinery co-op often functions as a network of technical dialogues between peers. These technical dialogues allow farmers to share their experiences, to compare their results and to confront their practices. By so doing, they can better draw valid conclusions from their on-farm observations. Labour-sharing arrangements are special opportunities for technical dialogues, because they allow each farmer to better know his peers' on-farm conditions and practices. The needed talks to share and adjust machinery also provide interesting opportunities for technical dialogues, through which machinery plays the role of the “intermediary object” among heterogeneous farmers.

The local technical dialogues network triggered from the machinery co-op functions better if some farmer members are connected to other networks or study groups, or interact with other sources of knowledge. In most of the studied machinery co-ops, some farmers are connected to a study group or a regional peer-to-peer network devoted to no-tillage farming. This allows them to regularly participate in activities, such as training sessions, lectures, study trips, etc. Other farmers may benefit from the knowledge drawn from these activities through the technical dialogues with the “connected” farmers.

Each socio-technical network associated with the machinery co-op does not provide equal opportunities for taking part in the technical dialogues. In some socio-technical networks, the technical dialogues tend to be more concentrated on a few farmers associated through multiple sharing arrangements.

Moreover, few study groups and networks exist in France devoted to legume improvement and integration in farming systems. As a result, the interviewed farmers find it difficult to better master and improve the practices regarding this topic. This appears as an “orphan topic” when compared with existing no-tillage networks (Landel, 2015) and visible progress among no-tillage practising farmers over the long term.

Optimising work organisation

Many labour-sharing arrangements are organised through the socio-technical network associated with the machinery co-op. We identify the following arrangements: joint organisation of the tasks to be carried out, individual specialisation within farmers' groups, and mutual aid. These allow farmers to optimise the on-farm work organisation. Indeed, the changes may imply additional operations at the farm-level, such as experimental activities, observation and improvement of ecological processes, and coordination tasks (especially if the new practices induce integration of a new crop or activity). Several machinery co-ops studied seek to delegate some tasks to common paid employees, especially through newly emerging pools of employers among farmers. These may allow them to dedicate more time to experimental activities, or to participate in study groups or thematic networks to access adequate knowledge to improve their practices.

Considering farmers' collective arrangements as a local arena for agroecological transition

These results show how the search for autonomy and the collective organisation lead the studied farmers towards low-input and more diversified farming systems with a better use of the ecological functionalities. In a context of disappointments regarding agricultural institutions, the machinery co-op, which is a self-controlled farmers' organisation, appears as a relevant support to ensure their autonomy. The discussed examples show how the incremental change process can result in a systemic change over the long term. Moreover, the cooperative principles of the machinery co-op also ensure the practices durability over the long term. Indeed, the commitment contract ties each member to a minimal level of equipment use for several years. This was also observed by Ploeg in other agricultural contexts; through cooperation between farmers, the on-farm shifts tend to become enduring (2008). Finally, these results also echo other studies highlighting the role of experience- and knowledge-sharing in farmers' networks (Forney, 2016; Compagnone & Hellec, 2015).

This research reveals how environmental schemes may benefit from existing collective farmers' arrangements, using them as a local arena for agroecological transition. First, we find it important to consider the farmers' search for autonomy as a potential starting point for agroecology. This is why we suggest designing the agri-environmental schemes at the local level in partnership with farmers' collectives. This seems to us a relevant way for farmers to participate in configuring the scheme in the sense that it strengthens their autonomy. Secondly, we highlight the need to support technical dialogues within local networks of farmers' arrangements to facilitate equal conditions for farmers to take part in the dialogues. Thirdly, supporting the possible connections between study groups and peer-to-peer thematic networks with local farmers' arrangements appears as a strategic means to improve change processes.

Developing boundary spanning between conventional and organic farming communities appears as an interesting strategy regarding the role of the diverse sources of knowledge that interviewed farmers may access and connect with to improve their practices. That is why we call for new facilitation processes between organic and conventional farmers. We recommend putting shared items (machinery, equipment, strategic resources) centre-stage to facilitate dialogue, rather than belief systems and values. Indeed, in the studied machinery co-ops, the shared equipment and resources play a strategic role of "intermediary object" that facilitates technical dialogues. Indeed, to focus the dialogue on technical or material issues may avoid dealing with controversial ecological issues.

Conclusion

This paper highlights some features of the increasing desire among conventional farmers to develop their autonomy. In the last fifteen years, different ecological and socioeconomic pressures have triggered the need for farmers to gain more autonomy from the markets and the dominant socio-technical regime. The studied farmers become more autonomous by reducing the external inputs and by improving the use of their internal resources.

They manage to develop their autonomy owing to both kinds of collective organisation. First, they are members of a farm machinery co-op which is associated with a local socio-technical network of farmers' sharing arrangements, which facilitates the cooperation among peers.

These allow farmers to better face logistics needs, to improve and to access strategic resources and to optimise their work organisation. Secondly, some of the interviewed farmers belong to study groups or peer-to-peer thematic networks that connect them to different sources of knowledge. This allows them to get away from advisory services which fail to provide the required knowledge for agroecological transition. These “connected” farmers may share adequate knowledge and their vanguard experiences through the technical dialogues that occur in the local arrangement network associated with the machinery co-op.

The paper reveals the potential to make the most of existing collective farmers' arrangements to turn them into a local arena for agroecological transition.

The collective innovation movement visible in the machinery co-ops induces new questions for the national network. Firstly, study groups and peer-to-peer thematic networks are complementary farmers' organisations which allow machinery co-ops to act as strategic niches for agroecological innovation. More cross-disciplinary partnerships between these organisations, and including research institutions, appear essential to develop the means for farmers to become more autonomous. Secondly, any social movement currently appears as a voice of the conventional farmers who develop agroecological practices to become more autonomous. The national network of machinery co-ops might become a protagonist, perhaps with other farmers' organisations, to represent this social group and promote their concerns, efforts, successful experiences and specific needs.

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Informed participatory research, a methodological approach for investigating the potential of organic farming in the transition of food systems

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Abstract: A study on the prospects for organic agriculture in 2025 suggested four possible evolution scenarios; from the most optimistic, where organic farming would be the main agricultural model, to the most pessimistic, where organic farming would have been diluted into a new form of sustainable conventional agriculture. Two main elements could lead to the most pessimistic scenario. The first element is the heterogeneity of organic farming (e.g. different scales, various levels of mechanisation, varying degrees of adherence to agroecological principles). This diversity complicates organisation among farmers and is potentially confusing for consumers. The second element is the development of short food marketing channels that give priority to local products regardless of their organic farming status. The role of research is not to decide on the best pathway in the transition of farming systems, but to provide the tools for investigating the possible pathways and for supporting decision-making. In this regard, we developed a series of 'informed participatory research' (IPR) steps designed for use by research centres. IPR combines the classic elements of participatory research and a specific, comprehensive and multi-dimensional assessment of the diversity of farming systems. The method has been implemented in Wallonia, Belgium, where public institutions are supporting a strategic plan for the development of organic farming. The IPR approach provides a way of integrating technical and social tools within a dynamic framework of analysis and action.

Keywords: Organic, transition pathways, informed-participatory-research, research institution, production systems

Introduction: organic farming at the crossroads

Recent meta-analyses comparing conventional and organic farming systems have provided scientific evidence on the positive impact of organic agriculture (OA) on the environment, employment, food quality and the reduced use of antibiotics for livestock (Tuomisto et al., 2012; Tuck et al., 2014; Baret 2015). Nevertheless, key indicators such as profit and yield are still higher in conventional agricultural systems (Crowder & Reganold, 2015). A recent meta-analysis (Ponisio et al., 2014) showed that appropriate investment in agroecological research aimed at improving OA management systems could greatly reduce or eliminate the yield gap between organic and conventional farming systems for some crops and regions. A fair comparison between organic and conventional options is difficult because it depends on the farming systems (De Ponti et al., 2012; Baret, 2016) and because one of the principles of OA is the management of contextual resources at the farm and regional scales (e.g. climate, landscape topography). OA approaches are therefore highly site-specific (Rigby & Cáceres, 2001; Lamine & Bellon, 2009).

Despite the limited investment in research on OA, this sector's share of the market is increasing in most European countries. This could be related to consumer awareness of the importance of their food choices (impact on health and environment), but also to a change of mind among farmers, who see in OA both an economic opportunity and a benefit for their own health and for the sustainability of their farms. In Wallonia, in the southern part of Belgium, OA has enjoyed strong growth since 2005. In 2014, the threshold of 10% of Walloon farmers in OA was passed. The consumption of organic products in Belgium has been consistently increasing since 2008 ('Les Chiffres Du Bio 2014 | Biowallonie' 2016). About 7% of Belgian families consume organic products on a weekly basis and, in 2014, nearly nine out of 10 Belgians consumed organic products. In Europe, the land under OA increased by 78% between 2004 and 2014, and in eight European countries more than 10% of agricultural land is now under OA (Willer & Lernoud 2016).

The focus on OA by consumers, farmers, researchers and public authorities is clearly increasing. A study on the prospects for OA in 2025 suggested four possible scenarios for this agricultural model ('4 Scénarios Pour Le Bio à L'horizon 2025', 2016). One scenario, labelled 'Bio-based', shows that, in the context of a serious food and environmental crisis, OA would be an obvious choice and would be the main model for French agriculture. Conversely, the 'Bio-suspect' scenario envisages the dilution of organic farming into a sustainable local agricultural system because OA would be discredited by such problems as traceability (e.g. suspected fraud) and serious medical crises (e.g. *Escherichia coli*). The conventional sector, with greater media and PR capacity than the organic sector, could send stronger messages to the consumer.

Zanoli et al. (2012) suggested that the drivers of the future development of OA are, first, support policies and, second, consumer demand. Whatever the drivers, OA remains a potential solution to the main ecological and economic challenges facing food systems (De Schutter & Vanloqueren, 2011) and is a key option for farming systems in a resource-constrained world (Freibauer et al., 2011). Further development of OA approaches will require considerable investment in research and the development of OA-specific methodologies.

At the European level, OA research funding is low and declining (Baret et al., 2015). In this context, research should focus on the efficient use of available resources. OA is highly knowledge intensive and dependent on context, which suggests that a participatory research approach building on farmers' knowledge would be more efficient than a conventional top-down approach (MacMillan & Benton, 2014). Gibbon (2002) defined participatory research as an active partnership of farmers and other key stakeholders in the research process from design to evaluation. Participatory research is often associated with the issue of technology adoption in developing countries. In the context of OA in Europe, the main attraction of participatory research is that it offers better integration of farmers' expectations, knowledge and constraints (Eksvärd & Rydberg, 2010). The challenge of participatory research is to bridge the gap between the conventional knowledge of farmers and the abstract knowledge of scientists.

The contextualised nature of OA practices and systems also means that organic systems are diverse.

The rationale of this paper is that prior knowledge of the diversity of farming practices and systems should be the starting point of the participatory research process. Data collected from farmers should be shared with participants in the participatory research process if the research is to be relevant and grounded in reality. We have called this approach 'informed participatory research' (IPR).

In this paper, we focus on the specific context of OA in Wallonia, where the government is supporting OA research. The challenge is to develop new avenues of research. Given the diversity of OA systems (see next section), we propose a participatory approach based on integrating the information about these diverse practices and systems.

Diversity of organic agriculture models

Diverse practices in organic farming

Unlike non-organic farming, OA is controlled by its own regulations, specifications and labelling. Organic production relies on a diversity of techniques and socio-economic models, from the most agroecological systems of production to quasi-industrial systems. Given this diversity of OA systems, different options can be considered and research on OA should take this range of options into account.

The production system used by an organic producer depends on several factors, including the history and suitability of the land, the influence of the family and the level of mechanisation. Opportunities and obstacles, level of education, professional experience off the farm and farming experience itself are all part of a personal history that affects a farmer's perspective, which is a major driver of the technical choices made (Vanwindekens et al., 2013). Factors such as socio-cultural background, farming background of the family, presence of old and/or young generations also have an impact on choice of production practices and marketing channels. For example, market gardening is attracting young producers, many of whom are not from farming families and are therefore not constrained by socio-cultural history. They have a strong ecological vision of farming and most of them are developing small-scale agroecological organic systems (Dumont & Baret, 2016).

Diversity of systems of organic vegetable production

With regard to vegetable production in the Walloon region, we identified four main models, ranging from market gardeners working on a few hectares to cereal farmers who included some vegetables in their crop rotation (more details on this study are available in Dumont and Baret, 2016). In each model the producers had similar histories, socio-cultural backgrounds and work orientations. The first group comprises market gardeners with a small area (less than 2.5 ha) who try to prioritise ecological values, as well as paying attention to profitability. Producers with larger areas (2.5 - 7 ha) and a higher level of mechanisation are also very concerned with environmental issues, but they take more account of the current socio-economic context. They prioritise certain social issues for their workers, particularly in terms of training and welfare at work. Both these groups want to participate in building an agroecological paradigm. The third group of vegetable producers is the most mechanised. They put more emphasis on economic criteria, even though they have chosen OA for ecological and health reasons. Some of them, alongside the producers in the fourth group (growing vegetables in field crops) produce organic vegetables purely for economic reasons. As time goes by, many of them feel increasingly concerned about environmental issues, but they still implement new practices only when they consider these practices to be at least as cost-effective as conventional practices. They use conventional practices for some of their fields and often see organic practices in terms of input substitution. This observation could be specific to the Walloon region context, where there are very few vegetable farmers.

Organic, local or sustainable conventional farming?
The multiplicity of production systems leads to confusion among consumers. For example, producers seen as participating in the promotion of OA (Bellon & Lamine, 2009) (i.e. in the third and fourth groups described earlier) are sometimes criticised for selling their products abroad or to supermarkets (Dumont et al., 2016) and/or for not applying agroecological production practices.

New elements are also blurring the distinction between organic and sustainable conventional agriculture. These include: (1) conventional producers who claim to use organic practices; (2) organic producers who do not want to pay for OA certification (for various reasons, e.g. they are in a precarious financial situation, lack assured land ownership, consider certification more suited to industrial OA, cannot cope with the administrative load); and (3) farmers who simultaneously use both conventional and organic farming practices.

In addition, consumers lack a clear vision of the heterogeneity of production models in the OA sector and therefore do not understand why the same vegetable product with the same origin can be sold at very different prices. For example, vegetable boxes from local producers are often sold via cyber-commerce at very different prices across the Walloon region. Boxes sold directly by producers who are market gardeners on small acreages tend to be more expensive because each producer personally produces a diversity of vegetables and therefore has a high workload. Consumers usually cannot choose the vegetables contained in these boxes. Boxes that are cheaper and contain a combination of vegetables chosen by the consumer tend to be those produced by the third and fourth groups described earlier, as well as foreign producers and wholesalers.

Consumers lack the information they need to make informed choices when buying organic products. Many of them think it is better to buy local products from conventional small farmers who use some organic practices or work in sustainable agriculture than to buy generic products certified as organic. They try to find the right balance between price, quality and support for local and sustainable agriculture.

How research can take account of farming system diversity and support transition pathways

Identifying the diversity of situations is the first element in the IPR process. A given innovation (e.g. a new variety or tool) will not have the same impact or the same relevance in different farming systems (Van Damme et al., 2014). The identification of this diversity of systems highlights the need for a system level approach to complement the plant and plot levels.

Is a systemic and participatory approach the best option for organic farming?
As OA is based on the agroecological paradigm in agriculture (Vanloqueren & Baret, 2009), systemic participatory research is a prerequisite for the methodological approach.

Participatory approaches are based on a new vision of relationships among farmers, other stakeholders and scientists. From a political point of view, they should help to build consensus on intricate issues such as environmental impact and genetically modified (GM) crops. Within the theory of innovation, participatory approaches are often contrasted with the top-down diffusion of innovation. As noted by Landel (2012), participatory methodology is redefining power relationships in the research and development process and this redefinition could lead to new technical options for sustainable development in agriculture. Using participatory methods, both scientific and empirical knowledge are valued and farmers' needs and constraints are taken on board right at the outset of the process of innovation. Participatory methods seem to be more appropriate for producing evidence for action and sustainable development (Cornwall & Jewkes, 1995).

Participatory approaches are often presented as positive and relevant for achieving more sustainable food systems, but there are drawbacks. In a comparative study of conservation agriculture in France and Brazil, Landel (2015) showed that when participation meant collaboration among economic stakeholders to produce evidence and efficient technologies for a particular model of conservation agriculture, the imbalance in terms of information and knowledge between private stakeholders (mainly agricultural suppliers) and farmers favoured a vision of conservation agriculture that relied on using chemical herbicides and neglected other more ecological practices, such as OA. The rules of participatory processes were followed and all the stakeholders had the same level of investment, but the commercial company experts contributed most of the technical knowledge and their influence was therefore critical in determining the technical pathways. Thus, the participatory approach paradoxically reduced the farmers' freedom of choice. The most sustainable option was not promoted and conservation agriculture was restricted to the chemical based version. The significant drawbacks in this situation were the lack of technical knowledge among local stakeholders and the power held by the commercial stakeholders because they had mastered the requisite knowledge.

The Informed Participatory Research (IPR) approach

The methodology proposed in this paper is being implemented within the context of a new OA research strategy in Wallonia. First, we will describe the overall process, with all the steps (Figure 1), and then we will outline how the process is being implemented in Wallonia. The process has not been fully completed yet, but the first results are promising.

Our concept of IPR comprises both the classic elements of participatory research and a specific, comprehensive and multi-dimensional assessment of farming system diversity that is used as an input in the participatory process.

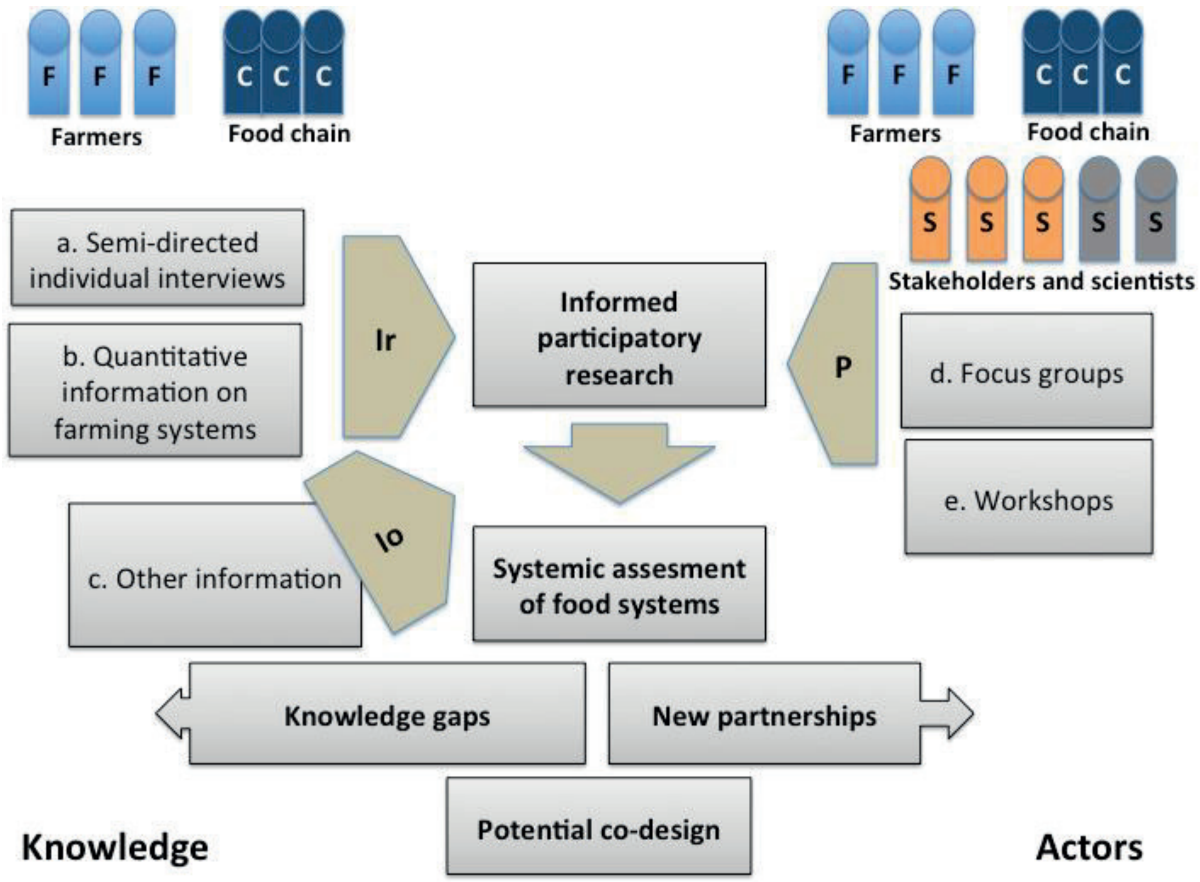

Figure 1. Scheme of the Informed Participatory Research process

IPR is based on two pillars. One is the collection of data on the diversity of food systems from farmers and other stakeholders in the food chain. The data, based on (a) interviews with individual actors and (b) quantitative information, is called 'reflexive information' (Ir) because it is based mainly on information collected directly from with actors. These actors include those involved in the transition to OA as well as conventional producers in the mainstream system, Complementary information can be collected from other sources (Io). All this information (Ir and Io) constitutes the initial input into multi-actor discussions.

The second pillar is the use of (d) focus groups and (e) workshops, which extends the set of stakeholders to scientists. The participatory information (P) collected during focus groups comes from small meetings of 6-12 farmers in which a researcher (or facilitator) uses some inputs (in our case TresoGest, see below) to initiate an exchange of information among the farmers. During the workshops, Ir, Io and P information is brought to the participants (multi-actors in the scheme) for sharing and elaboration. The overall process results in a systemic assessment of food systems. Knowledge gaps are discussed with the stakeholders in the information process (scientists and experts, as well as farmers and others involved in the food chain). With the stakeholder dimension, the participatory process gives rise to new partnerships in overcoming obstacles. In some cases it leads to the co-design of innovations.

IPR is rooted in a comprehensive and objective description of reality. The aim is to identify: (1) types of agriculture; (2) visions of agriculture; and (3) the tensions and synergies among these types and visions that favour or hinder transition, in addition to the classic elements of participatory research.

In order to address these issues we suggest using approaches such as comparative agriculture (Cochet, 2011) with comprehensive sociological tools. This type of approach allows room for understanding the complexity of reality, including all relevant actors affected by transition, and it highlights the multiple links among the diverse types of agriculture.

The present study has shown the importance of research on knowledge gaps. Producers, like consumers, do not always have enough information on the different production types in order to make important decisions. For example, some market gardeners with small acreages who want to participate in an agroecological paradigm will use tools with lower fuel efficiency (e.g. a rototiller replacing a tractor) in an effort to reduce the impact of mechanisation on the environment, although there is no evidence of lower fuel consumption. Others might move to a system based on using a small tractor to reduce their work burden, but this requires an acreage increase.

Tentative implementation of IPR in organic farming in Wallonia
In the development of an OA Research Plan for Wallonia, we have tried to apply these principles.

As a first step, we took account of the diversity of practices for each type of OA (mixed livestock, field crop, pig and poultry, vegetable and fruit). For that, we identified a network of 43 innovative OA farms. On each of these farms, we sought to (1) document the practices and (2) identify the needs with regard to technical advice and related research via 90 semi-directed interviews during a process of network building. The two objectives will be refined during frequent field visits, with quantitative measurements and discussions on practices and constraints with each farmer (Ir in Figure 1). In parallel, the College of Farmers, a new institution officially responsible for consulting farmers, set up a process of consultation with the entire OA sector through focus groups and online surveys. The participation of OA farmers in this process was higher than that of conventional farmers, for which the College also has responsibility in terms of the identification of needs.

We then compiled a list of the needs identified through the 90 interviews on the 43 farms, the results of the College of Farmers consultation and the questions raised in interactions with farmers and other stakeholders during various meetings. The resulting file contained 280 items, all with their origin identified.

For the identified issues, the practices and research linked to these needs were documented (Io in Figure 1) and used as a basis for discussions of the different scenarios at participatory thematic workshops. These workshops with farmers were prepared in consultation with skilled extension, training and consultation stakeholders. The information emerging from the workshops was integrated into the overall review and knowledge base (P in Figure 1).

For example, we conducted a workshop with six farmers engaged in mixed-livestock farming where we used an economic tool, TresoGest, to examine the system of farming practices. TresoGest is based on spreadsheets on which farmers input their income and expenditure so as to obtain an overview of their revenue. The detailed costs for each accounting unit (e.g. feed, veterinary care) are presented in a comparative framework, with the agreement of the farmers. This fostered an exchange of experiences among the farmers about their practices. The use of tools such as TresoGest has various benefits, including: (1) generating interest and confidence among farmers; (2) covering a wide range of topics, from production practices to marketing channels; (3) giving farmers a sense of ownership of their data; and (4) providing a wide range of reliable and detailed quantitative and qualitative data.

The accumulated information and the workshops helped to identify the knowledge gaps that needed to be addressed by research and to define the type of research required, such as techno-oriented trials, experimentation on farms and multi-actor collaboration. For example, in the case of cattle fattening, in addition to the technical skills needed to produce a quality product, with the possible contribution of research, there is the issue of marketing being locked-in. Unlocking the marketing process would involve changing retailers' specifications, among other things. In this respect, scientific evidence such as taste tests could be used to lobby retailers more effectively. This would not be enough to unlock the system, however; other actors need to be involved. In the case of pig meat production, this outcome could be achieved by training producers and by making all (e.g. technical, trade-related) information available to encourage them set up producers' organisations that would be strong enough to talk to retailers and access suitable distribution channels. These training workshops would be conducted in cooperation with research, extension and organic farmers' organisations).

The collaboration between research centres and other research institutions, such as universities, is crucial for ensuring a comprehensive description of farming systems, the development of analytical tools and a good balance between qualitative and quantitative dimensions.

The added value of applying informed participatory research

Transition pathways need not only funding for developing specific technical research, but also new methodologies and tools for addressing new types of issues. OA is holistic in essence, and when farmers first move into OA they tend to have very limited access to information about it. In many cases, their main adviser is another farmer, and often met by accident. Many farmers have to look for information abroad. Thus, farmers build up their own expertise and knowledge network. All this points to the need for systemic and participatory research methods that are not widely used in research centres. By using reflexive information (Ir) tools, the IPR approach helps to avoid an imbalance in information collected from the actors involved.

We have also shown that in agriculture in general there is a diversity of OA models. OA can contribute to a transition or to a change in the paradigm in an agroecological way. However, there is a real threat to OA. As researchers, our role is not to promote a particular model, but to provide the tools and methodologies that will support stakeholders along their transition pathway. We propose IPR as a suitable approach for documenting the diversity of options and providing the keys to understand the reasons for and consequences of this diversity. We hope that this methodology can be extended to any type of agriculture. In addition, by highlighting the knowledge gaps, IPR provides researchers with guidelines for the thematic research needed within the context of the reality of the various options.

The emergence of systemic issues documented by the actor stakeholders rooted in the real situation implies the development of new partnerships among actors but the different levels of knowledge could lead to imbalances among these actors. The IPR approach ensures a fair share of information among them.

The IPR approach offers a way of integrating technical and social tools within a dynamic framework of analysis and action.

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