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THEME 5 – SMART TECHNOLOGIES IN FARMING AND FOOD SYSTEMS

Smart Farming indicates application of different forms of digitalisation in the agriculture sector, such as sensor driven agriculture (e.g. Precision Farming), the use of Big Data for analytical purposes to inform decision making, application of the Internet of Things (e.g. in quality control, producer-consumer relationships), and (autonomous) devices such as robots and drones. Digitalisation is not only a technological matter. It is also associated with new actors from outside agriculture (SMEs, upstream and downstream, service firms, etc.) and with new relations between actors. Whilst the potential benefits of these technologies are very easy to understand at a local scale, their potential impacts on farming systems have not been fully evaluated. Digitalisation is likely to affect and possibly disrupt the agricultural sector beyond the farm gate, influencing supply chain processes, logistics or consumer related information, knowledge and innovation systems, and can have pervasive social, economic, ecological and ethical consequences.

HOW DIGITALIZATION AFFECTS THE CAPACITY OF THE FARMING SECTOR TO ASSESS INNOVATION? THE CASE OF DIGITAL DECISION SUPPORT TOOLS FOR FERTILIZATION IN FRANCE.

Noémie Bechtet, Pierre Labarthe

INRAE France

Abstract: Promotors of precision farming claim these technologies can optimise agricultural production, value chains and food systems (Bellon Maurel and Huyghe 2017; Smith 2018). In the specific case of fertilization, digitalization relies on the use of digital decision support tools (DSTs) that aim at optimizing yield of the crop production and limiting fertilizer losses that can cause nitrogen contamination of groundwater. DSTs aim at helping farmers in overcoming economic and legal challenges.

Yet, several authors argue that there is a need for more evidence about the impacts of those tools on the sustainability of the farming sector (Balafoutis et al. 2017; Koutsos and Menexes 2017; Lioutas and Charatsari 2020). The question of the control of the recommendations given by these tools is particularly important. It is all the more relevant in a context where the privatisation and fragmentation of the supply of advice leads to new challenges about the control of the diffusion and evaluation of innovation (Knierim et al. 2017; Prager et al. 2016). Moreover, digitalization transforms internal logics of advisory suppliers, with for instance the emergence of new needs of capabilities for advisory suppliers (Fielke et al. 2020). In this paper, we aim at investigate the impacts of digitalization on the capacity of advisory suppliers of the farming sector to assess digital innovations that are subject to uncertainties and controversies.

To do so, we conducted in depth semi-structured interviews with designers and diffusers of DSTs in France. The aim was to identify the evaluation activities of the innovation made along this chain, with a specific focus on the role of advisory actors from the farming sector.

Preliminary results show that all actors realize intangible evaluation activities of the innovation. Private companies that design the innovation invest on data and analytics to build their expertise for such evaluation. Advisory suppliers from the farming sector (cooperatives, agricultural chambers and technical institute) support intangible but also tangible evaluation activities. Yet, they don’t invest a lot of resources for evaluation activities.

Hence, this paper underlines the changing role of advisory suppliers: they use digital innovations to charge farmers for their expertise but their investments to assess the innovation is limited. Growing differentiation between their investments in front office activities and back office activities highlights the risk that advisory suppliers lose their capacity to assess the innovation. This leaves the space for agribusiness organizations that design digital innovations to set the rules for an evaluation based on the use of analytics and data.

EXPLORING THE ADOPTION OF INNOVATIVE SPRAYING EQUIPMENT

Alex Koutsouris[a], Vassiliki Kanaki[a], Emilio Gil[b], Paolo Balsari[c], Sebastien Codis[d], David Nuyttens[e], Spyros Fountas[a]

[a] University of Athens, Greece
[b] Universitat Politècnica de Catalunya, Spain
[c] Universita degli Studi di Torino, Italy
[d] Institut Francais de la Vigne et du Vin, France
[e] Instituut voor landbouw en visserijonderzoek, Belgium

Abstract

The purpose of this paper is to explore factors impeding the adoption of innovative spraying equipment as well as farmers' information and training needs (i.e. demands for/from extension/innovation support services). Data have been collected, in the framework of INNOSETA project, through a survey in 7 EU countries, based on a questionnaire addressing both adopters and non-adopters of innovative spraying equipment. A total of 348 questionnaires were collected and analysed using multivariate data analysis. Furthermore, 32 experts representing research/academia, the industry and extension/advisory organisations have been interviewed, based on an aide-memoire. The combination of the analyses of the two data sets produce interesting results concerning the support of the adoption of such technologies (including subsidizations, legislation, equipment characteristics, etc.) and the role of advisory/extension services.

Introduction[87]

Plant Protection Products (PPP) industry and research have been developing more sustainable, novel PPPs; at the same time, spraying technologies have experienced important improvements in terms of efficiency and safety, including in their development the latest advances in electronics, data management and safety aspects. But unfortunately, there is still an important gap between research developments and the actual use of the available equipment by farmers, especially the large number of small and medium producers with limited access to relevant information[88]. If this gap closes, then European agriculture could become more sustainable with minimum environmental, socioeconomic and human health impact. Therefore the need for agricultural stakeholders to gain knowledge of existing and future technological advancements in spraying technology as well as of adequate training in all of the European territory which will allow for the implementation of the EU legal framework and thus the production of food in a better and more sustainable way.

The H2020 project INNOSETA is organized to explore spraying application needs in the most commonly used crops (cereals, vegetables, orchards, vineyards and greenhouses) in seven European hubs (see below). The aim of INNOSETA is to set-up a Thematic Network on "Innovative Spraying Equipment, Training and Advising" designed for the effective exchange between researchers, industry, extension services and farming community. This network will link directly applicable research and commercial solutions and grassroots level needs and innovative ideas thus contributing to close the research and innovation divide in this area.

Among others, the INNOSETA project aims at assessing end-users' needs and interests and at identifying the factors that influence farmers' generation shift, adoption and diffusion of innovative spraying technologies. In this paper some of the results of the data analysis, collected through farmers' survey (see below) are presented.

[87] See INNOSETA project proposal.
[88] www.topps-life.org

Theoretical background

The literature review (Koutsouris and Kanaki, 2018) undertaken in order to provide an understanding of farmers' innovation-related behavior explored, on the one hand, main theories and models (e.g. Diffusion of Innovations – DOI (Rogers, 2003); Technology Appeptance Model – TAM (Venkatesh and Davis, 2000; Venkatesh and Bala, 2008); Agricultural (Knowledge and) Innovation Systems – A(K)IS (see Koutsouris, 2019); the Spiral of Innovations (Wielinga and Koutsouris, 2018),'Triggering Change' model (Sutherland et al., 2012), etc.) and, on the other hand, papers and reports related to spaying equipment and best practices adoption as well as elevant meta-analyses, focusing on the developed world.

With reference to the latter, for example, Thornton et al. (2017), in the first place, underline that the adoption of improved agricultural technologies and practices by farmers has often been less than expected despite demonstrated benefits. And quoting Orr (2012), they state that there are many contributing factors to that, including inherent limitations of supply-led approaches, limited attention to context-specificity and to farmers' priorities, and lack of appreciation of the socioeconomic, political and institutional contexts within which smallholder farmers operate.

Long et al. (2016) in their exploration of climate-smart agriculture (CSA) claim that its adoption in OECD countries is slow. Based on their literature review and a series of interviews in the Netherlands, France, Switzerland and Italy, they came to the conclusion that major impending factors are costs and other financial factors, overly complex language and 'jargon', and policy and regulatory issues (subsidies as well as lack of appreciation, in policy and research, of day-to-day farm realities) along with a lack of awareness of CSA and associated technological innovations.

Antolini et al. (2015) in their review of studies (largely concerning Brazil and the U.S.) on determinants of adoption of Precision Agriculture Technologies (PAT), show that the adoption drivers of major influence are related to: a) socio-economic factors (gender, age, education, family size, residence place, influence in decision making, experience in agriculture, experience with PAT, ability to obtain and process information, networking, membership in associations and cooperatives, financing and credit sources, risk aversion and organization level of producers in the region); b) agro-ecological (i.e. biophysical) factors (farm tenure, size, technologies and specialization, productivity, revenue, etc.); c) institutional factors which influence the behavioral change of the farmer (region and distance to input and output markets); d) information sources (access and perceived usefulness of consultants, extension services, technical companies, etc.); e) farmer's perception of the technological attributes such as relative advantage of certain technology, visibility of results, compatibility with existing technologies in the farm and the opportunity to experiment PAT; and f) technological factors, i.e. level of mechanization technology and adoption of technologies by the farmer.

Pignatti et al. (2015) based on a series of interviews with key-informants in Greece, Turkey and Italy, conclude that adoption of ICT and technological innovations in agriculture is strongly connected with a list of drivers including: a) farmers' socio-demographic characteristics: age, education, behavioural traits (entrepreneurial attitude, open-mindedness, attitude towards changes, propensity, fear and anxiety, etc.), knowledge and awareness; b) farms' structural features: land ownership, farm size, economic status, farm business and targeting markets, perspectives and planning, production type and farm's organization, location; c) innovations' features, such as: ease of use, usability, simplicity, compatibility with existing systems, flexibility, along with effectiveness, usefulness, observability of performance, reliability, degree of fitting, potential and perceived benefits, profitability, price/performance ratio and return on investments as well as provision of understandable feedbacks and ready-to-use information outputs; d) external environment: trusted and competent support system (re: farmers' awareness raising, decision process and evaluation); and, e) public funding, agricultural policies and market conditions.

De Baerdemaeker (2014) based on a number of examples of new technology adoption in the U.S. (tractors, milking robots, renewable energy technologies, rollover protective structures on tractors) note the difficulty of new technologies to replace existing technologies and highlight that the adoption of new technologies involves considerable change in farming practices. The author, in the same vein with Diekmann and Batte (2014), who explored the adoption of precision weed control technologies among U.S. farmers, states that the adoption of new technologies is affected by the perceptions of the potential users, learning requirements for their introduction, economics (costs both for the user and the supplier) and the financial or regulatory stimuli/incentives (including support in the form of demonstrations, extension services, etc.) from governments, nongovernment organizations, retailers, and/or consumers along with a systemic approach to integrated weed management (i.e. the building of robustness and redundancy into the system).

Pierpaolia et al. (2013), with reference to their literature review on Precision Agriculture (PA) technologies, claim that the most important aspects influencing the adoption of PA technologies are: farm size; costs reduction or higher revenues to acquire a positive benefit/cost ratio; total income; land tenure; farmers' education; familiarity with computers; access to information (via extension services, service provider, technology sellers); location. On the other hand, the intention to adopt depends on perceived 'usefulness' and 'ease of use' along with technology costs (a perception of both high monetary cost and cost related to the difficulty in the use of technology), the quality of soil and farm size and farmers' skills and relevant competences. They therefore suggest that on-farm demonstrations, free trial and support services (which promote the perception that new technologies are easy to use) along with the simplicity and compatibility of PA tools can enhance adoption.

Knierim et al. (2019) in their exploration of the adoption of smart-farming technologies (SFTs) in 7 European counties found out that farmers, although they have a positive view towards them, underline a broad range of barriers vis-à-vis their implementation. This, in turn, requires a better adjustment of technologies to farmers' needs and farm conditions as well as an improved enabling environment, in particular access to SFT related information, training and advisory services and to reliable digital infrastructure.

In their review Koutsouris and Kanaki (2018), along with Knierim et al. (2019), made clear that innovation adoption and diffusion is undoubtedly multifactorial with various factors, such as farmers' and farms' characteristics, biophysical, socio-cultural and institutional environment influencing the process of adoption, that is, if and how innovations are adopted; furthermore, the heterogeneity of both farms and farmers affects what is adopted, to what extent, and when. Moreover, the inconsistent evidence found in the literature review further points to the need for caution regarding, on the one hand, the use and measure of variables and, on the other hand, the different contexts (biophysical environment and cultural-historical patterns) within which research is conducted along with the characteristics of the technology under research. Reference has also to be made to the role of extension/advisory services and consultants which, in the framework of Agricultural Knowledge and Innovation Systems (AKIS), influence farmers' awareness, knowledge and skills. The literature review (theories and research results) provided the rational for the construction of both the questionnaire for the farmers' survey and the interview schedule for the experts' interviews carried out in the framework of the INNOSETA project.

Methodology

Our study covered 7 different European hubs: France, Greece, Italy, The Netherlands and Belgium, Poland, Spain, and Sweden. Five cropping systems were selected throughout all regions, i.e. arable crops, open field vegetables, orchards, greenhouses and vineyards (Table 1).

Table 1. Cropping systems per hub.

Spain	Orchards, Vineyards, Greenhouses
Italy	Orchards, Vineyards, Cereals
France	Orchards, Vineyards, Cereals

Greece	Orchards, Vineyards, Greenhouses
The Netherlands & Belgium	Cereals, Vegetables, Greenhouses
Sweden	Cereals, Vegetables, Orchards
Poland	Cereals, Vegetables, Orchards

Source: INNOSETA Grant Agreement

According to the project's Grant Agreement a) attention should be given to the fact that both adopters and non-adopters are included in the sample; b) the objective is to account and grasp the different needs and priorities of farmers in relation to their different socio-economic characteristics; and c) up to 50 interviews with farmers from the pre-classified groups should be conducted by the national partners, either personal or telephonic, using the specifically designed for this project questionnaire. Therefore, in the first place, it was decided to interview 50 farmers in each hub, comprising 25 adopters and 25 non-adopters per hub. Following, based on the contribution (%), in terms of utilized agricultural area (UAA), of each of the selected cropping systems per country a first estimation of the sample (no of farms/farmers per cropping system per country) was made. In order to grasp differences, we categorized the population (total number of farms/farmers) in each cropping system into size classes (ha.) following EUROSTAT 2013 data sets. Thus, based on the EUROSTAT 2013 data concerning the farm size classes for each of the cropping systems per country, a detailed sampling schedule (no of farms/farmers per size per cropping system per country) was put together. Finally, in order to have enough farms/farmers in the least represented cropping systems (ca 10 farms/farmers in each hub and around 30 farms/farmers in total with respect to each of greenhouses, open field vegetables and vineyards), with a view to data analysis, the sample was adjusted as shown in Table 2 (following again the farm size classes rationale in order to select farms/farmers).

Table 2. INNOSETA sampling (farmers' survey)

	Initial sampling	Adjusted sampling	Collected questionnaires
Cereals	200	144	142
Open field vegetables	18	34	29
Orchards	104	102	101
Greenhouses	10	32	32
Vineyards	24	40	44
TOTAL	356	352	348

The questionnaire comprised 102 closed, Likert-type and open questions divided in 8 sections: farm's characteristics; spraying equipment and machinery; innovative spraying equipment; adopters (or non-adopters) opinions on innovative spraying equipment; best management practices (PPP application); information seeking; farmer's innovativeness; and farmer's characteristics. Data were collected by partners, entered in appropriate EXCEL data basis (built by AUA) and analyzed with the use of SPSS for Windows (ver. 23.0).

Furthermore, a number of experts, i.e. those who are involved in agricultural technology development and innovation processes such as researchers/ academics, industry representatives, extensionists/advisors and/or farmers (representatives of cooperatives/ associations) were interviewed; the target was to interview 5 experts per hub. The interview guide comprised 18 open questions/topics addressing issues such as the current challenges and the role of innovative spraying equipment in overcoming them; the advantages and disadvantages of innovative spraying equipment for farmers; reasons for which farmers adopt (or do not adopt) innovative spraying equipment and the like. The expert interviews were conducted face-to-face, via telephone or Skype, recorded and transcribed to produce computer-generated documents and analysed per topic (exploratory analysis; Sarantakos, 2005). Overall 35 interviews were conducted. Emphasis was given to the expert groups *Research* (9), *Industry* (9) and *Advisors* (9) especially vis-à-vis the *Farmers*' group (3) as farmers were specifically targeted through the survey; 5 *Academics* were also inetrviewed.

Results

Farmers' survey

<u>General characteristics</u>

The vast majority of the interviewees own the spraying equipment they use (93%). In 20 out of the 348 cases they use a subcontractor (in 15 cases along with the use of their own equipment by themselves). The adopters of one of the innovative spraying equipment (selected by the project experts) are 204 (58.6% of the sample).

Farming is the primary occupation for 81.3% of all the interviewees. The majority of the interviewees operate their own family farm (83%); companies represent 16% and cooperative farms 1% of the sample.

The majority of the interviewees fall in the age category 40-59 years old (55%); farmers up to 40 years old account for 28% of the sample with farmers aged 60 years old and over being the 17% of the sample[89]. Up to 10 years of experience in farming have 24% of the interviewees with 29% having more than 30 years in farming. All other classes of experience (11-20 and 21-30) account, each, for 19-28% of the farmers[90].

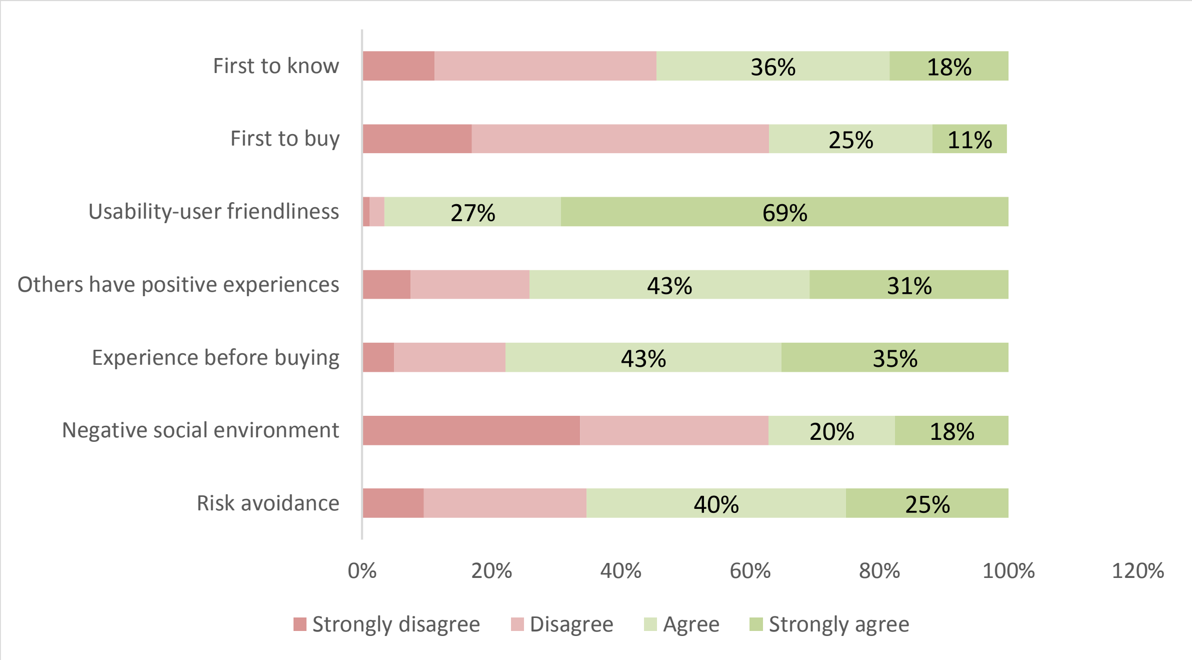
In general, the interviewees have good (secondary 26% and technical 42%) to higher educational level (university 22%)[91]. Furthermore, 93.6% hold the Training Certificate on PPP use according to the Directive 2009/128/EC while 61% have attended training courses in spraying machinery[92].

In general, adopters and non-adopters do not show any statistically significant difference in terms of age, gender, education and farm size (both owned and rented land) as well as years in farming and the existence of a successor - or not. Non-family farms (companies, cooperatives) are more likely to use innovative spraying equipment than family farms (P=0.001). Adopters and non-adopters do not differ in terms of holding a Training Certificate on PPP use but adopters are more likely to have attended a course on spraying machinery (P<0.10).

The interviewees claim that usability and user-friendliness are very important to them when they buy new things (97%) thus that they prefer to have some experience with something before they buy them (78%) and wait to buy new things, until they know that others have positive experiences with it (74%). Therefore, although they are the first to know about new machinery/technology in their social circles (54%) they are not the first to buy (63%). In general, they don't like taking risks (risk avoidance) with their farming business (65%). Finally, if interested, they would buy new equipment even if their (social) environment would be negative on it (63%).

[89] Farmers' age is differentiated per cropping systems with orchards and vineyards cultivators being younger.
[90] Farmers with orchards or vineyards are the least experienced in farming and with spraying applications (P<0.05).
[91] The majority of the farmers with greenhouses have primary and secondary education while the majority of the farmers with cereals and vegetables have technical education; more farmers (%) with orchards or vineyards have tertiary education as compared to the farmers with other cropping systems.
[92] Farmers with cereals or open filed vegetables are the ones who have been mostly trained on both PPP use and spraying machinery with farmers with greenhouses being the least trained in spraying machinery.

Figure 1: Farmer's innovativeness



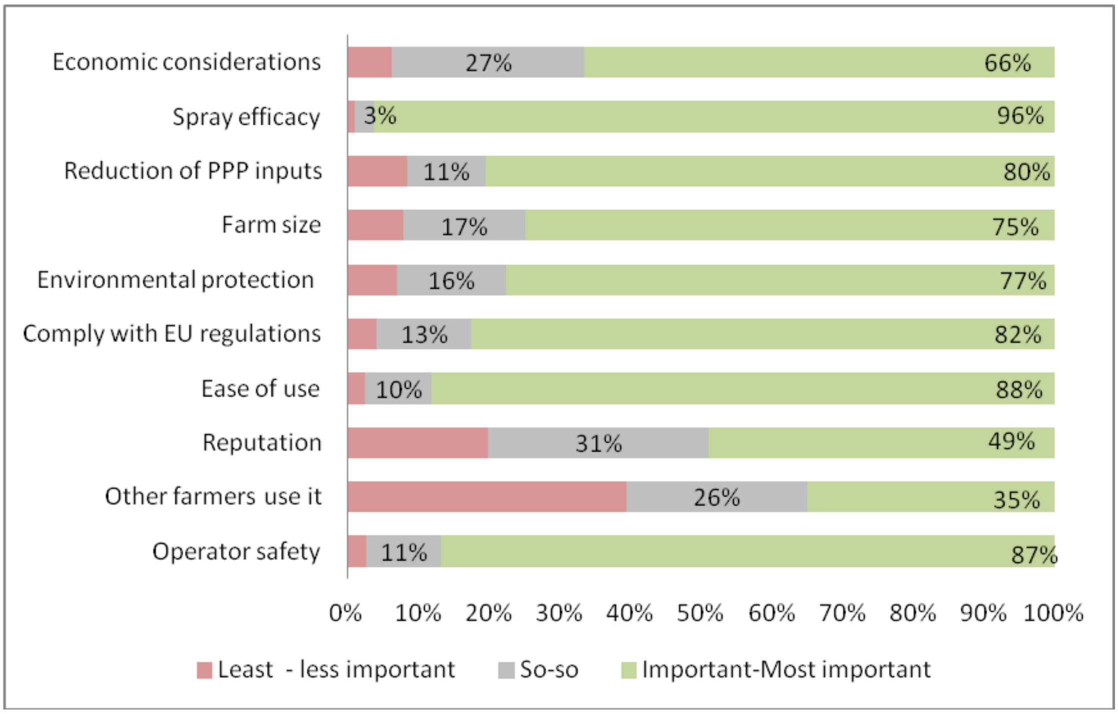
Adopters are more likely to be the first in their social circle of friends and relatives both to know about and buy new machinery/technology (P=0.000). On the other hand, non-adopters are more likely to wait to buy new things, until they know others have positive experiences with it (P<0.010) and prefer to have some experience with something before I buy it (P=0.001) as compared to adopters.

<u>Spraying equipment characteristics and adoption</u>

Concerning the criteria which affect interviewees' decisions on buying/choosing spraying equipment (Figure 2) 'spraying efficacy' (96%), 'ease of use' (88%) and 'operator safety' (87%) predominate followed by 'compliance with EU Regulations' (82%), 'reduction of PPP inputs' (80%), 'environmental protection' (77%) and 'farm size' (75%). 'Economic considerations' (66%) appear to be an important criterion (although less important than the aforementioned ones) with 'reputation (of the manufacturer)' (49%) and the fact that 'other farmers use it' (35%) being least important. Some farmers further added reliability (14 cases) and technical support/service (13 cases). Economic considerations are more important for non-adopters (P<0.05), while the reduction of PPP inputs and environmental protection are less important (P<0.05)[93].

[93] Economic consideration and farm size are less important for greenhouse growers; compliance with the EU rules is more important for farmers cultivating cereals and open field vegetables; and the fact that 'other farmers use it' is mostly important for growers with orchards/vineyards.

Figure 2: Criteria for buying spraying equipment



In general, adopters state that their innovative spraying equipment are easy to work with (96%), reliable (95%) and economically justified (90%); additionally, it is easy to get technical support for their equipment (87%) and they do not require a lot of maintenance (57%). Farmers also disagree with the statement that "sharing costs with other farmers has allowed you to use this spraying equipment" (83%).

Figure 3: Adopter's opinions on the innovative spraying equipment they have

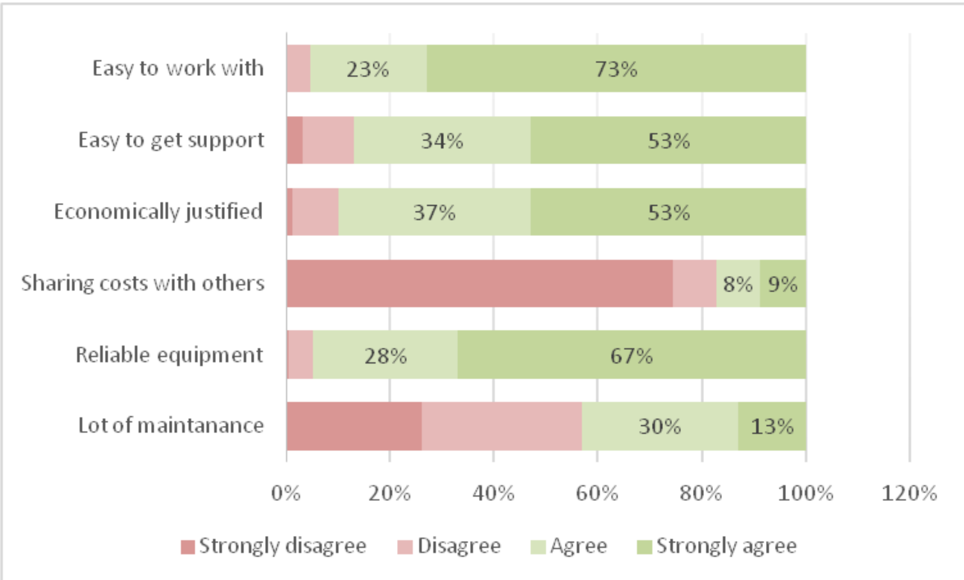
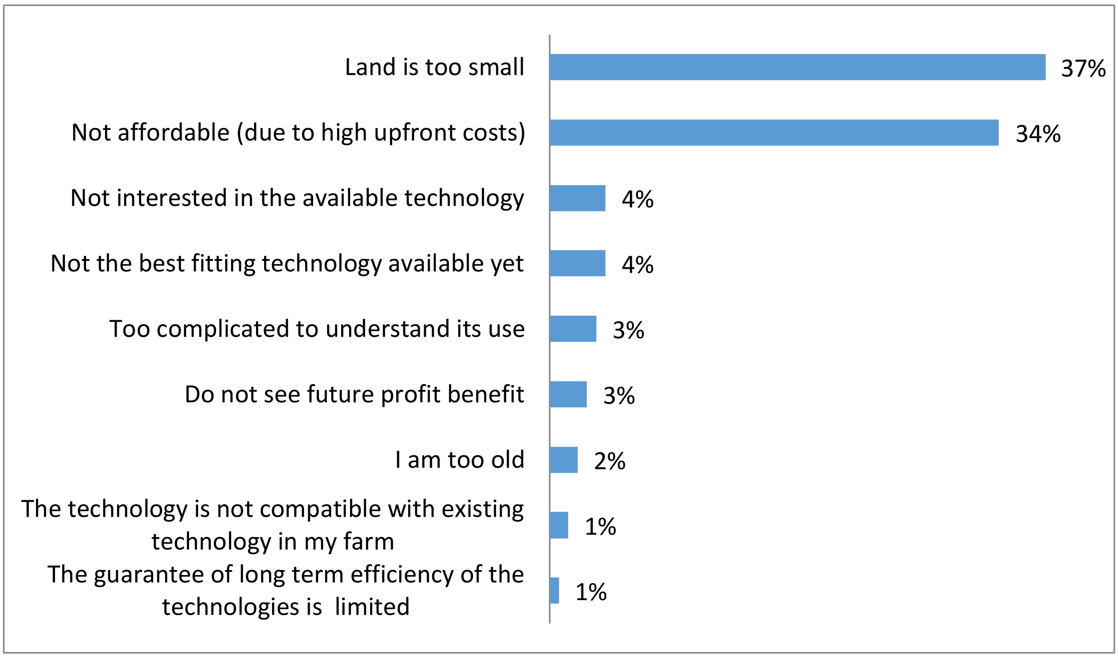


Figure 4: Most important reason for non-adopting innovatory spraying equipment



According to non-adopters the main reason for not having innovatory spraying equipment owes to their small sized farms (37%) and that they cannot afford it (34%). When five reasons pertaining non-adoption are aggregated, again the issues of affordability and small farms prevail (21% and 18% respectively)[94] with all other reasons ranging between 5% and 8%[95].

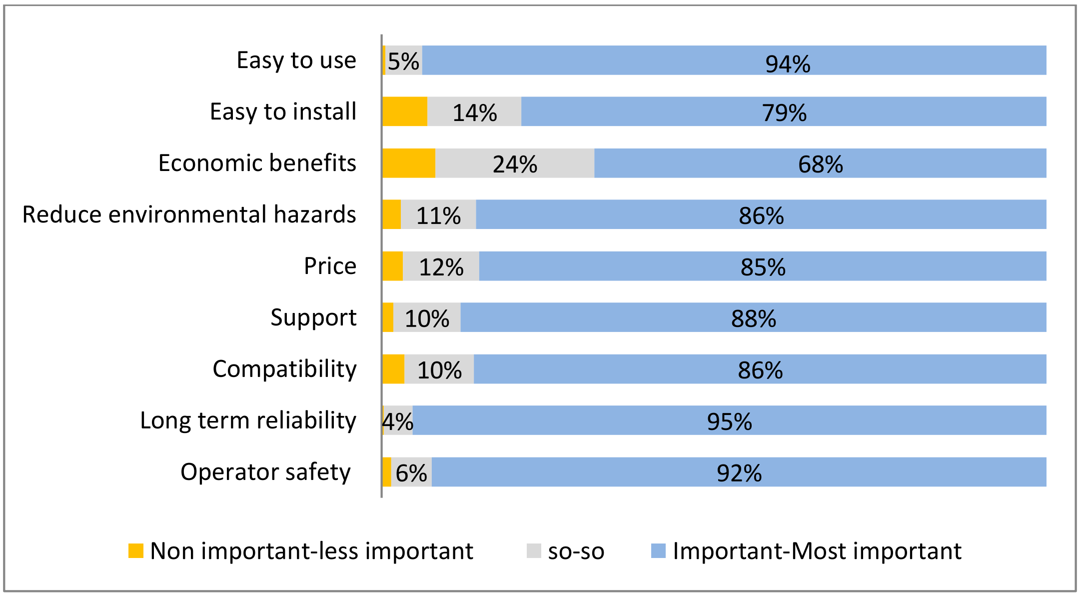
According to the interviewed farmers the most important spraying equipment characteristics that would make spraying equipment more relevant to farmers' needs (Figure 5) are long term reliability (95%), ease of use (94%) and operator safety (92%), followed by the availability of technical support (88%), compatibility with the existing machinery (86%), the reduction of environmental hazards (86%) and price (85%). Finally, easiness to install the equipment (79%) and economic benefits (68%) are important equipment characteristics for the majority. Adopters put more emphasis to the ease of use ($P<0.05$) and to the availability of technical support ($P<0.05$) than non-adopters[96].

[94] The main reason per cropping system is as follows. For cereals and open field vegetables: not affordable (19%), small size (17%), do not see future profit/benefit (12%); for orchards and vineyards: not affordable (25%), small size (19%); for greenhouses: small size (24%), technical assistance not guaranteed (13%), not affordable (10%).

[95] Other refers to 30 answers among which the most important are: 'do not need it/my old machine works well' (11), 'not handy' (3) and 'not suitable for the morphology of the farm' (3).

[96] Economic benefits and compatibility with the existing machinery seem less important for cereal and open field vegetables cultivators while long term reliability seems to be more important for orchard/vineyards growers.

Figure 5: Characteristics that would make spraying equipment more relevant to farmers' needs



Interviewees were also asked about the incentives they would like to see in future policies to facilitate the acquisition of innovative spraying equipment. Two out of three asked for some kind of financial support, in principle the subsidization of the purchase of innovative spraying equipment. Other financial incentives, albeit with few supporters, include tax reductions (8), reduced equipment prices (18) and higher/fair prices for their produces (20); some also ask for non-repayable incentives (17) as well as long term mortgages or exemption from VAT. In parallel, some ask special treatment (increased support) for small-scale farms (10), support to certified and/or high precision equipment (3) as well as the reduction of bureaucracy (6).

Furthermore, one out of seven asked for training and technical support from independent (extension/advice) providers. Training is somewhat more frequently asked for as compared to technical support and information dissemination; the demand for demonstration, on top of the demand for technical support, is also interesting to notice (12 farmers).

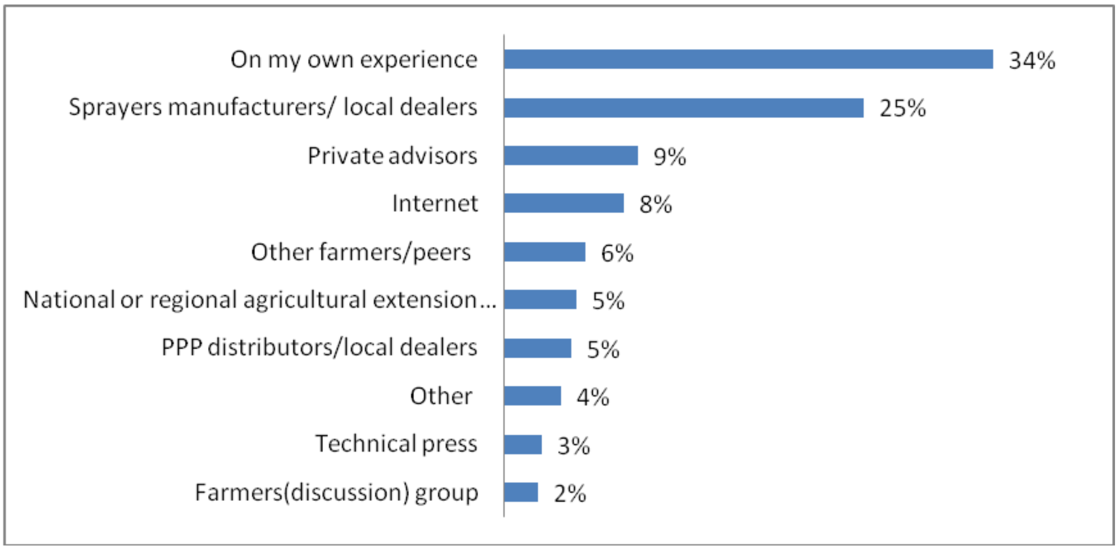
The change of regulations towards, for example, more strict inspections, compulsory use of Low Drift Nozzles and the like is supported by one out of ten. Another 10% maintain that the characteristics of the equipment (especially spraying efficiency followed by ease-of-use) could be a good incentive for adoption as well. However, around 5% of the farmers declare that they do not need/ wish to have any incentives

<u>Sources of information</u>

Regarding the most important source of knowledge/know-how on the use and operation of their spraying equipment is concerned (Figure 6) interviewees said that they rely on their own experience (34%) followed by information/advice from equipment manufacturers and dealers (25%) and advisors (private: 9% and public/cooperative: 5%)[97].

[97] The most important source of knowledge/know-how on the use and operation of their spraying equipment differs between farmers with different cropping systems. Farmers with cereals and open field vegetables mainly mention their own experience closely followed by the industry (sprayers' manufacturers, PPP distributors and their dealers); farmers with orchards/vineyards equally mention the industry and their own experience; and growers with greenhouses their own experience followed away by advisors (private or public).

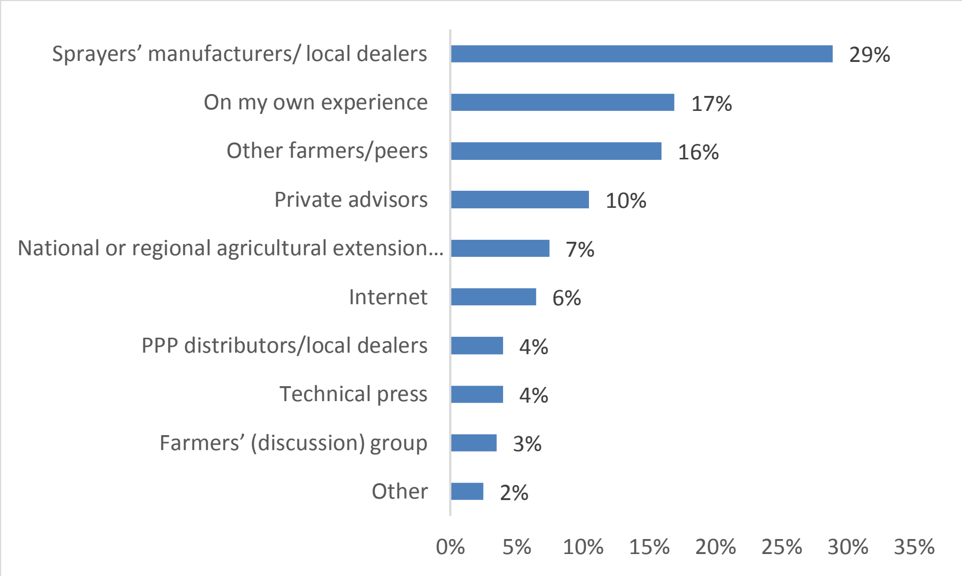
Figure 6: Most important source of knowledge/know-how on the use and operation of spraying equipment



Adopters and non-adopters seem to consider different sources of knowledge/know-how on the use and operation of their spraying equipment as being more important to them ($P<0.05$). Non-adopters rely much more on their own experience (as compared to adopters as well as to other sources of information) while adopters more on the industry (sprayers' and PPP manufacturers/dealers).

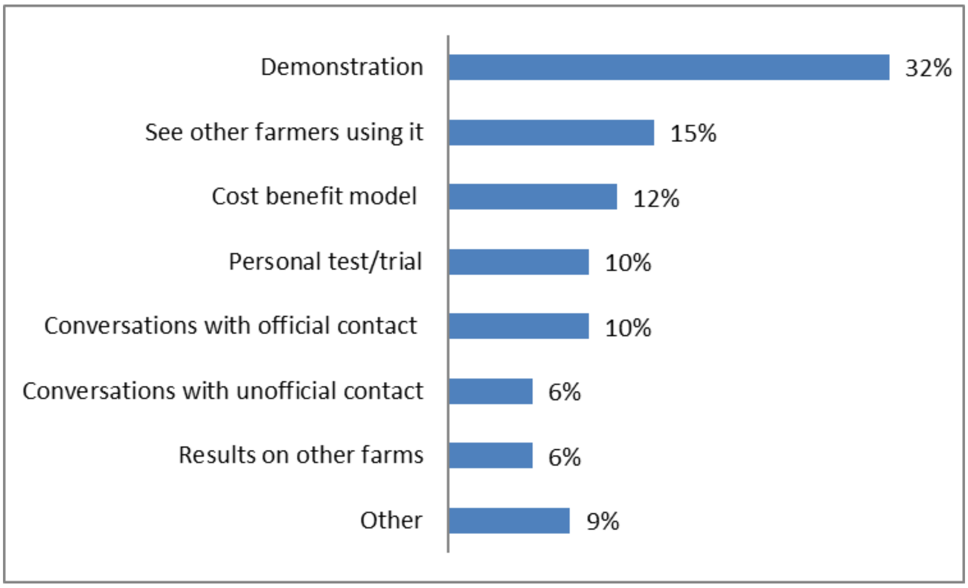
When the three most important sources of information are taken together again farmers' own experience (23% of all the answers to the questions) and equipment manufacturers and dealers (21%) predominate followed by advisors (private: 9% and public/cooperative: 5%), other farmers (9% other peers and 4% farmer groups) and the Internet (11%).

Figure 7: Adopters' most important information source on buying innovative spraying equipment



The most important adopters' source of information on buying innovative spraying equipment is sprayers' manufacturers/ dealers (29%) followed by farmers' own experience (17%), other farmers (16%) and private advisors (10%). All the other sources of information account for less than 10% each. When the three most inportant information sources are aggregated, sprayers' manufacturers/ local dealers (24%) along with other farmers/peers and their own experience (15% each) predominate. All the other sources of information account for less than 10% each. Additionally, the majority of the adopters did not test the equipment before buying it (70.6%)[98].

Figure 8: Information source non-adopters trust the most for buying innovative spraying equipment



Non-adopters said that the most important source/piece of information/test they would trust before deciding to purchase innovative spraying equipment are demonstrations (32%), other farmers using the equipment (15%), a cost-benefit model tailored to their farm (12%) as well as a personal trial or conversation with someone with advisory capacity (10%). 'Other' refers to 13 cases out of which 4 refer to extension/advisory service and another 4 to the Internet. When it comes to the three most important

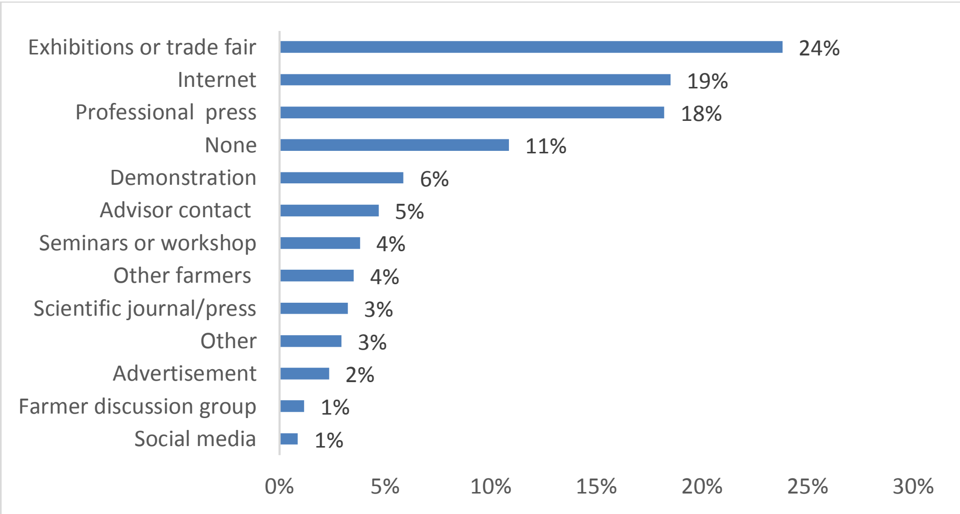
[98] This is mostly true for open field cultivations (around 27% of the farmers tested the machinery) while 50% of the farmers with greenhouses said they tested the equipment they were going to buy.

sources/pieces of information/tests demonstrations still lead (19%), followed by personal trials (15%) and other farmers using the equipment (13%). Conversations with someone with advisory capacity as well as results on other farms are equally important at 12% closely followed by a cost-benefit model tailored to their farms (11%) and conversations with peers and neighbors (9%).

Furthermore, non-adopters claim that they would buy innovative spraying equipment if they would get a subsidy (84%) as well as relevant training (68%) and to a much lesser degree if they could share initial (purchase) costs (28%).

The majority of the sample said that they visit agricultural fairs, field days/demonstrations, or exhibitions at least once a year (86%) – notably 51% more than once per year. Only 4% said that they have never visited such an event[99]. Adopters visit agricultural fairs, field days/demonstrations, or exhibitions more often than non-adopters (P<0.05).

Figure 9: Most recent source of information regarding innovative spraying equipment



Interviewees claim that the most recent source of information in which they sought out information in relation to innovative spraying equipment are exhibitions or trade fairs (24%), the Internet (19%) and professional press (18%), followed by demonstrations (6%), and advisors (5%). No relevant information during the year the interview was carried out (2018) was sought by 11% of the farmers. When the three most recent sources of information are aggregated exhibitions or trade fairs (23%), the Internet (16%) and professional press (14%) prevail, followed by demonstrations (9%), peers (8%), advisors (7%) and scientific journals/press (6%) .

Experts' interviews

In general, experts agree that, on the one hand, spraying equipment has to be further improved to face current challenges and, on the other hand, farmers must become not only aware of new technology but trained and supported on both new equipment and PPP. The industry representatives notice that technology becomes 'more expensive and more susceptible to failures' and this is an additional challenge for R&D while advisers underline the need to understand the complexity of on-farm (under real conditions) plant protection.

According to the experts, the main advantage of the adoption of innovative spraying equipment relates to spraying effectiveness and its environmental and economic (reduction of costs) benefits. Other positive aspects relate to operator health and safety as well as to compliance with legislation and work

[99] Farmers with different cropping systems manifest different behaviors. Three quarters of the farmers with green houses visit more than once a year; 90% of the farmers with cereals and open field vegetables visit at least once a year; 20% of the farmers with orchards or vineyards visit less than once a year or never.

comfort; professional pride and positive public image were also mentioned. These, in turn, are for the experts (although with differences in their ranking) the main incentives for farmers to adopt innovative spraying equipment, esp. when there are tangible results farmers can see ‘in their environment’.

On the other hand, experts unanimously pointed to the high initial (purchase) costs of such equipment as being their main disadvantage (for some, such costs are not justified), followed by (as aforementioned) the need for the continuous training of the farmers. Some also pointed to the fact that such equipment is complex and vulnerable - thus the need for quick access to technical support. It was also argued that farmers may feel insecure due to both the fact some technologies may have not been proven in practice (under real local conditions) and the continuous changes in technology and legislation. Farmers further underline the need to combine environmental protection with agronomic efficacy and farm/household economy along with relevant legislation.

According to the experts farm size (bigger farms), farmer’s age (younger farmers), education and ‘personality – mentality’ (technology enthusiasts, professional farmers, willing to experiment, open-minded) are most likely to be the factors that characterize the adopters of innovative equipment and practices. Production intensification, membership in farmers’ groups or companies (vs. family farms) and public image were also mentioned, esp. by industry represenatives, as affecting adoption. According to extensionists the forefront factor pertaining adoption is farmers‘ environmental consciousness. Farmers additionally point to social pressure and legilation.

With regard to the main constraints vis-à-vis the adoption of innovative spraying equipment and practices experts point, besides affordability, to farmers’ technophobia. The latter relates to the lack of training, farmers‘ low educational level, unawareness about new technology, along with occasionally contradicting messages from the industry, confusion about legislation and equipment vulnerability. Advisors and researchers further point to unsuitable farms’ conditions and the pressure of farmers‘ immediate social environment while farmers also mention the fast developments in technology (including the expectation for better and cheaper equipment).

Given their preceding views, all experts state that the affordability of the innovative spraying equipment and the visibility/demonstrability of their benefits are key in supporting their wide adoption/use; the industry believes that profitability is a preceding factor. Other characteristics of the technologies, such as ease of use (user-friendliness) and maintenance, flexibility/adaptability, and reliability in time, are equally important. Farmers once more point to the need for technology to focus both on environmental protection and farmers‘ interests.

Experts thus support the subsidization of the purchase of innovative spraying equipment (especially for small farms). Scientists do so mainly due to the need to “renovate the sprayer fleet” – although there are also reservations as to the effectiveness of subsidies and the burden of the accompanying them bureaucratic procedures. On their part, industry representatives underline that subsidies should be targeted to equipment which meet certain requirements (for example, certified as environmentally friendly; precision spraying). Moreover, experts maintain that subsidies should not be the sole measure taken; stricter legislation (for example, ban the marketing of the least efficient sprayers or reward implementation of best practices) – given that such legislation will be coherent, clear and enforced (i.e. control mechanisms are put in place) along with information campaigns concerning the benefits of innovations, are deemed equally important. Farmers once more point to the the need to bring agricultural and environmental components together.

Furthermore, experts agree that the main R&D target groups are the most dynamic businesses, including big entrepreneurial family farms and companies (professionals/entrepreneurs and/or early adopters comprising potential clients) along with younger farmers and the most profitable crops. Therefore, according to some scientists (academics and researchers), despite the need for R&D to take into account farmers’ needs farmers are actually placed at the end of the innovation pipeline and do not have any chance to influence what happens at the other end; additionally, the low level of farmers’ education negatively affects the expression of precise and realistic demands to the industry. On the other hand, it is maintained that small-scale, local/regional companies take a closer look to their clients' needs as compared to larger national and/or international companies. Scientists said that innovation development is a process with its own dynamics and, although in spraying most developments are marginal/ incremental rather than radical ones, it is not possible to take into account all kinds of demands or to produce technology which will be suitable for everyone. Industry's and research programmes' policies affect the uptake of innovative ideas (including farmers' ideas). Advisors and farmers largely agree with scientists; for advisors the industry is more subject to pressures from legislation rather than to demands from farmers while farmers argued that the technology is mainly supply-driven than demand-driven resulting in a 'mismatch'. Contrary to such arguments the industry representatives maintain that there is two-way communication between farmers and the industry as well as that both actors are very important in technology development and thus their relationships must be improved.

Scientists underline the importance of extension/advisory services whose role is, on the one hand, to contribute to the wide diffusion of innovations (equipment, practices, PPP) through the provision of independent (neutral; objective), evidence-based information and practices (including training) to farmers and, on the other hand, to identify farmers' needs and inform industry. Among others, advisory services can assist farmers through independent tests and demonstrations as well as through the examination of the suitability of recommended best practices on their fields. Furthermore, extensionists claim that the establishment of communication links between the main stakeholders is imperative.

The experts note that despite the need for all the actors (possibly) comprising AKIS (re: the branch of innovative spraying technologies) to cooperate there is a profound lack of a comprehensive discussion/innovation platform on spraying equipment and difficulty to bring stakeholders together (especially on the horizontal level, i.e. competing manufacturers). They argue that extension/advisory services (should) intermediate between stakeholders, especially between farmers and researchers (farmers <-> extension <-> research) since they have good relationships with both of them. According to the scientists, the weakest link is policy, owing to its excessive slowness in decision-making and bureaucratic inefficiency along with the fact that decision-makers usually consult stakeholders other than farmers when they take measures about farming. The second most serious gap, according to scientists, is that between farmers and the industry; even if manufacturers interact with farmers they usually interact with a very small group which is not representative of the heterogeneity in farming. Such weak links between the interested parties result in gaps; the most characteristic one is the gap between theoretical/experimental developments and their applications in practice.

Conclusions

Innovation adoption and diffusion is undoubtedly multifactorial (Rogers, 2003); as aforementioned the heterogeneity of both farms and farmers affects what is adopted, to what extent, and when. In this piece of work, an attempt to identify factors impeding the wide adoption of innovatory spraying equipment was undertaken along with an exploration of the role of extension/advisory services in this regard.

In the first place, it is intresting to note that (most of) the interviewees/ farmers and (most of) the experts converge in their opinions concerning the measures to be taken to enhance the uptake of innovative spraying equipment. Experts agree with farmers for the need of targeted subsidization (certified machinery, best management practices, possibly more favorable for smaller farms). However, subsidies should not be the sole measure taken; stricter legislation and its enforcement, information campaigns, farmers' training and technical support by independent extension/advisory services are equally important.

Furthermore, equipment have to be improved in terms of the safety and comfort of the operator and ease-of-use, besides spraying efficacy and environmental and economic performance. The suitability of equipment for small farms as well as for difficult topographies has also to be underlined. Attention should be also given to farmers' demand for the better balance between environmental and agronomic performance of new technologies (spraying machinery and PPP).

As abovementioned, interviewees/ farmers asked for training and technical support from independent (extension/advice) providers while the interviewed experts, with reference to the low uptake and the complexity of new equipment, also stress the need to provide farmers with continuous training and technical support. On the other hand, it is important to notice the weak position of extension/advisory services among farmers' information sources on spraying equipment as well as the considerable percentage of farmers (esp. non-adopters) who are based on their experience. The need for extension/advisory services to engage with 'practice' activities like demonstrations[100] and participation in exhibitions or trade fairs as well as to assist farmers with their own trials and evaluations has been clearly shown, besides of course the intensification of other dissemination activities and the establishment of contacts with the 'hard to reach farmers' (including the internet and social media).

Finally, the lack of functional AKIS/ innovation platform in the branch of spraying technologies has to be underlined since it results in gaps which, although rather known to the actors concerned, are not bridged (with farmers in the weakest position, or isolation). In this respect, extension/advisory services seem to be in the best position (as compared to the other actors) to play an intermediation role (see Koutsouris, 2018), i.e. to negotiate with other actors the creation of the relevant AKIS network.

Despite the particular scope and sampling methodology followed in the INNOSETA project, these results may be of wider interest. The importance of exploring the topic of the adoption of innovative spraying equipment and the (potential) role of extension/advisory services is shown; further exploration is needed and is thus very welcome.

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FORESIGHTING THE FUTURE OF DIGITAL AGRICULTURE: FOUR PLAUSIBLE

Aysha Fleming[a], Andrew Terhorst[b], Bruce Taylor[a], Emma Jakku[a], Simon Fielke[a], Cara Stitzlein[b]

[a] CSIRO, Land and Water, Australia
[b]CSIRO, Data61, Australia

Abstract: Digital technologies offer agricultural systems around the world a myriad of potential opportunities. For some, the future has never looked brighter, for others it is more uncertain. To prepare for change and to understand the potential opportunities and consequences of smart farming technologies, fore-sighting is a recognized methodology to anticipate, learn and design strategies for change. Scenarios produced through fore-sighting are not guarantees of the future but ways to spark thinking and prepare for the unknown. This paper presents the results of a foresighting workshop that examined future smart farming scenarios in Australia. The workshop was conducted in Brisbane, Australia, in 2018 with leaders of CSIRO's 'Digiscape' future science platform - an initiative to build common big data infrastructure to transform decision-making and environmental action in Australian agriculture. The fore-sighting workshop posed the question: what does the future of Australian agriculture look like and what are the implications? Key social, economic, environmental, and technological trends that might impact agricultural knowledge and advice networks and supply chains, both in Australia and more globally, were presented and refined at the workshop. From this four plausible future scenarios emerged. Eight trends were identified: Accessibility and Connectivity; Proliferation and Integration; Consumer Demand and Traceability; Human and Social Capital; Globalisation; Farm Business Model Change; Environmental Stewardship and Services; and Resource and Environmental Uncertainty. From these eight trends, two axes were chosen to capture the most important drivers of change. The axes were: Resource and Environmental Uncertainty (vertical axis) and Farm Business Model Change (horizontal axis). The two axes created four quadrants which were each worked through by a different group at the workshop to produce four scenarios describing Australian agriculture in 2030. They were named: "Struggling", "Innovating", "Surviving" and "Thriving".

The scenarios serve as simple outlines of complex realities from which short to medium term inferences relating to digital agriculture can be explored and understood. They are not mutually exclusive or guaranteed, but they offer insights into potential issues and opportunities for digital agriculture development in Australia and more broadly. The implications identified from the scenarios, with lessons and potential applications for Digiscape and other digital agriculture projects relate to potential changes in farm business models, potential opportunities for new and improved decision making, both by landholder and others, potential beneficiaries and inequities of new technologies and interactions with digital technology and other components of food supply chains. The paper describes the scenarios and their implications in specific terms (changes that have been made to the strategic orientation of Digiscape) and more generally (lessons for other initaitives around the world).

POTENTIAL OF USING ICT TOOLS FOR CROP DISEASES MANAGEMENT AMONG HETEROGENEOUS FARMERS IN RWANDA

Michel Kabirigi[ab], Frans Hermans[b], Zhanli Sun[b]

[a]Rwanda Agriculture Board (RAB), Research department, Rwanda.
[b]Leibniz Institute of Agricultural Development in Transition Economies (IAMO), Germany.

ABSTRACT

Social interactions among farmers, extension agents, and government officials play a critical role in knowledge development and exchange, uptake of new practices, collective decision-making in agricultural practices. This is especially evident in developing countries where small-holder farming systems and subsistence agriculture prevail. Smartphones and new communication tools are likely to transform the way information exchange and social interactions take place. However, how these ICT developments will influence the communication and social interactions among farmers, and decision-making of farmers are intriguing questions, yet to be studied. Thus the aim of this study is to evaluate the use and experience of ICT of banana growers in Rwanda within the context of establishing an effective method for prevention and control of Banana Xanthomas Wilt (BXW), an infectious plant disease. Specifically, we want to assess whether farm clusters associate with the different behaviors and perceptions of the use of ICT. A structured questionnaire was used to collect household information from banana growers (n=690) in 8 representative districts across eight (out of ten) major agro-ecological zones within Rwanda. A combination of principal component analysis and cluster analysis was used to develop a farmer typology of banana growers. Three types of banana growers were identified, namely, i) Beer banana farmers characterized mainly by proportion of land allocated to beer banana and proportion of beer banana sold, ii) Livestock based farmers characterized mainly by high tropical livestock unit and higher education years of household head, and iii) Cooking banana farmers characterized mainly by proportion of land allocated to cooking banana and proportion of cooking banana sold. We then conducted a statistical analysis to regress the use of ICT on the farmer typology and other socioeconomic control variables. Results showed that cooking banana based farmers are more likely to own a smart phone and perceive ICT as very useful in effective control of BXW whereas beer banana farmers are less likely to own a smart phone; and they tend to perceive ICT as irrelevant in controlling BXW. Beer banana farmers are mainly limited by not knowing how to use these services which is associated with their low level of literacy while Livestock farmers prefer to get information from other sources. The studied farmers provide potential for using ICT (Mobile based) extension services however beer banana farmers, less likely to own smart phones, are limited to few options.

INTRODUCTION

Agricultural development is both crucial and global issue with increasing demand for the world to feed its population. The fact that the increase in yield does not grow in pace with the increase in food demand the food gap is expanded day by day signposting the potential of food shortage in the future (Long et al., 2015). Plant disease is one of major threats seriously compromising food production thus negatively affecting food security (Strange and Scott, 2005). For example the Banana Xanthomonas Wilt (BXW), caused by *Xanthomonas campestris* currently known as *Xanthomonas vasicola pv. Musacearum* (Biruma et al., 2007), has become the number one threat to banana intensification programs aiming at availing food for the increasing population in East and Central Africa (Nakato et al., 2014). Banana is a key crop, especially in eastern and central part of Africa, in the livelihoods of smallholder farmers occupying almost a quarter of arable land, contributing more than 50% to the diets (Gaidashova, 2006; Nkuba et al., 2015) and grown by 90% of households (Nsabimana et al., 2008). The crop is grown for 3 main purposes namely for cooking (41% of total banana cultivated area), for dessert (14% of total banana cultivated area) and for beer (45% of total banana cultivated area) in Rwanda (Bagamba et al., 1998; Nsabimana et al., 2008).

ICT tools and especially mobile phone-based ICT technologies have recently come up as a potential way of reorganizing extension system (Schut et al., 2016). The idea is that mobile phone-based ICT technologies, including smartphones and new communication tools, offers an opportunity to innovatively improve disease control efforts through timely surveillance of incidence. ICT technologies can improve communication among farmers themselves in the context of informal knowledge sharing networks which are developed because of limited operation in space of extension agents farmers create the (Vouters, 2017). A review by McCampbell et al. (2018) distinguished four intervention pathways for the application of citizen science and ICT within the context of effective control of this banana diseases in Central and East Africa. These four pathways are 1) providing data for prevention, 2) providing technical information for control, 3) providing knowledge to influence decision making, and 4) improving collective action. From this perspective, it is argued that the use of mobile based communication platform will enhance self-organized networks to timely diagnose BXW emerging outbreaks and to exchange knowledge which will lead to timely actions for prevention rather than control (McCampbell et al., 2018).

Although phone based ICT tools thus potentially offer many benefits the question of how these ICT developments will influence the communication and social interactions among farmers, and their subsequent decision-making are yet to be studied. As a first step towards answering this question, we aim to assess the different attitudes related to the use and perceptions of ICT related agricultural services (especially mobile phones) by different types of farmers. This is necessary because farms are diverse and heterogeneous in terms of socio-economic conditions which affect their behaviors on resource use and priorities hence the better understanding of this might explains differences in behaviors regarding production and consumption in agricultural production system (Tittonell et al., 2005; Barnes et al., 2011). Most of projects in agriculture are designed assuming that farmers are homogeneous hence interventions are similar to all. To some extent the low uptake of agricultural innovations has been associated with the failure of proper consideration of smallholder farm diversity (Coe et al., 2016; Hammond et al., 2017). A similar problem can be found with regard to the potential use of ICT. Although there have been studies to understand factors affecting farmers in adopting phone based services in agriculture (Islam and Grönlund, 2011; Adegbidi et al., 2012; Tadesse and Bahiigwa, 2015) these studies have also assumed that farmers are homogenous.

In this paper we use farm clustering to classify farm households based on socio-economic characteristics to understand how they would react differently to the adoption of new technologies based on their diverging priorities (Hammond et al., 2017). In this study we thus take farm diversity into consideration by discussing the use and perception of mobile based information delivery against banana farm clusters. Findings of this study will provide significant background information to projects targeting the use ICT based intervention for improved agricultural management.

METHODOLOGY

Study area

This study was performed in Rwanda, the country located in East Central Africa between latitudes 1°04’ and 2°51’ South and longitudes 28°45’ and 31°15’ East. In terms of area covered by banana in Districts, Muhanga, Gatsibo, Karongi and Rulindo have higher land allocated to banana production, equivalent to 22.5%, 11.1%, 10.1% and 7.1% respectively of the total agricultural area.

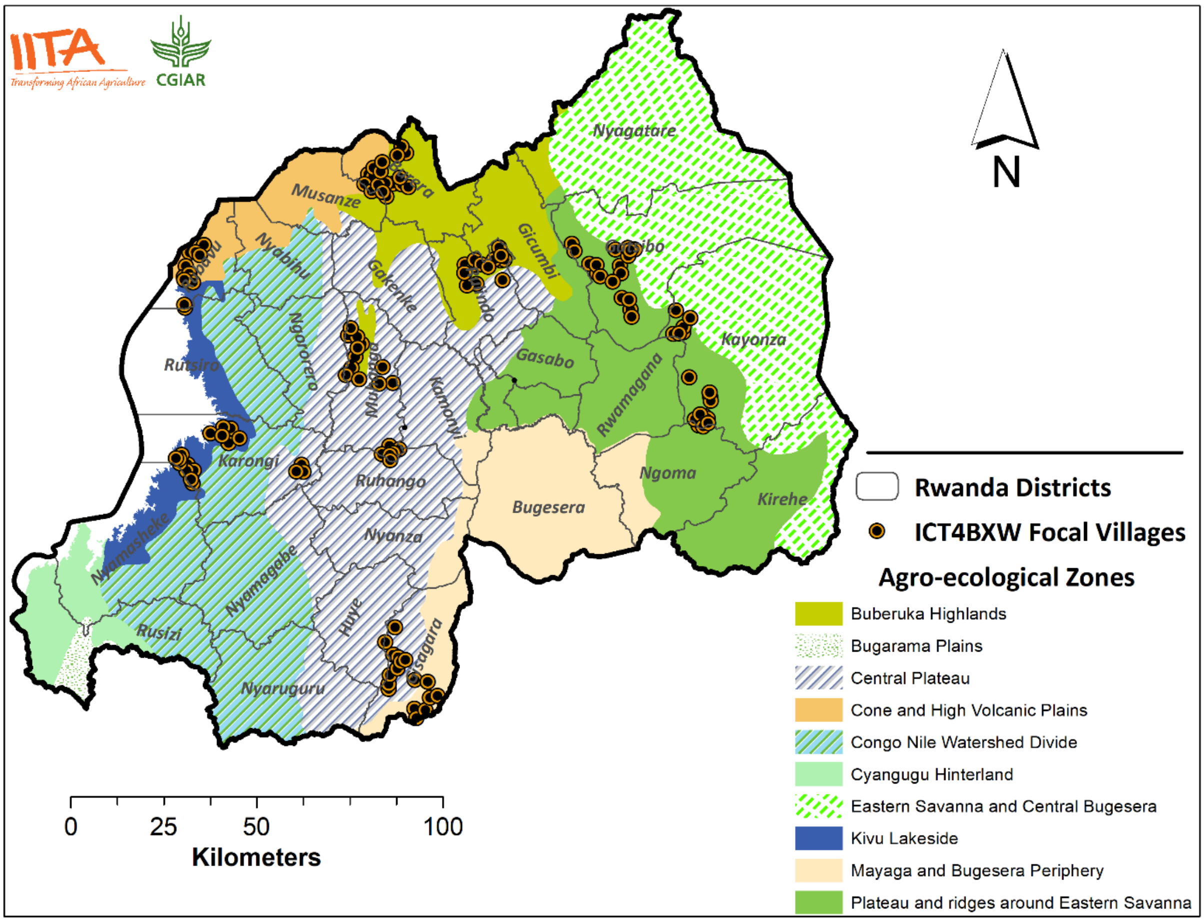


Figure 35: Study area

Sampling and data collection

The household survey was conducted in the period of July - August 2018 by trained RAB technicians from Banana program to establish the baseline of "Citizen Science and ICT for advancing the prevention and control of Banana Xanthomonas Wilt (BXW) in East and Central Africa" project. Within 8 selected districts Sectors and Cells were selected based on expert input from the district and sector agronomists. Stratified sampling was used to select villages, strata being the distance from District extension office and the incidence of BXW. Two criteria were considered when selecting villages: (1) distance between the village and the district headquarters whereby three-point scale was used (close, medium, and far) and (2) Level of BXW incidence whereby three-point scale was used (low, medium, high). Incidence levels were determined based on reports from sector and cell agronomists and field observations from RAB banana experts and technicians when passing through the village. The sampling team aimed for selection of villages with a minimum distance of 5km or a non-intervention and non-control village in between two selected villages. The selection of farmers considered gender of household head where amongst 5 farmers selected in each village 2 were female headed household and female enumerators were assigned to interview this category of farmers. The total expected number of farmers interviewed was 720 however only 690 farmers were interviewed reason being the lack of villages that falls within the 'long distance to the district headquarters' category in Rubavu District thus reducing the number of village from 144 to 138. The questionnaire used open, half open and closed questions, retrieving information at household level to establish baseline information for the "Citizen Science and ICT for advancing the prevention and control of Banana Xanthomonas Wilt (BXW) in East and Central Africa" project shortened as ICT4BXW. For this study we only analyze those questions of the survey that included ownership and use of mobile phones as ICT tool, relevance of ICT in BXW management and challenges farmers are facing in relation to the use of ICT in agriculture. General questions such as gender, age, education level characterizing respondents were included for analysis.

Data analysis

Principal component analysis (PCA), a data reduction method unmasking, through orthogonal transformation, hidden structures in a dataset was used to identify variables more explaining farm differences and identify components to be used in grouping farmers into clusters (Kourti, 2009; Barnes et al., 2011). Clustering was performed using hierarchical method where hierarchy bring close a tree like structure called dendogram and clusters are formed by connecting k+1 cluster solution into two clusters using group resemblances. Both descriptive and inferential statistics were performed. Column means was run to identify significant differences between farm clusters at 95% probability level. Dichotomous outcome variables of interest were subjected to a binary logistic regression analysis with independent explanatory dichotomous, categorical and continuous variables. We used FactoMineR an R package dedicated to multivariate data analysis (Lê et al., 2008) for principle component analysis and gplots R package to calculate and plot means (Bonebakker et al., 2012) in version 1.1.456 – © 2009-2018 RStudio.

RESULTS

PCA and clustering results

The figure 2 shows the scree plot highlighting 10 components, from a total of 12 variables which were included in PCA, whereby five components with eigenvalues greater than 1 retained for cluster analysis explain 63.3% of the total variation. The figure also presents variables contribution to the construction of two main components (explaining 32.5% of the variation) where the land allocated to beer banana or cooking banana are the main variables contributing whereas extension number received contribution is not so significant.

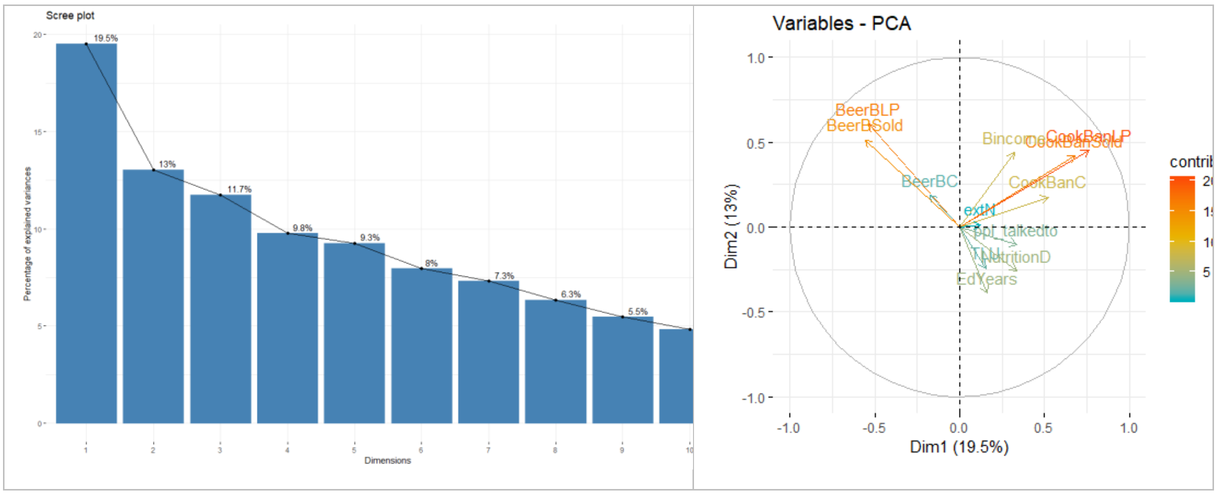


Figure 36: Principal component analysis Scree plot and contribution of variables to components

The table 1 presents identified variables responsible for farm heterogeneities which can be summarized in 3 groups namely farm/respondent characteristics (Nutrition Diversity and Education Years), type of banana grown, distribution in the field and use (Cooking or beer banana with their respective proportion of land allocated to them, banana income and promotion sold and consumed) and access to extension services (Extension number and People talked to). By observing the v.test values, which indicate if the mean of the cluster is lower or greater than the overall mean, we could name clusters considering that higher values of v.test show variables that are more associated with the cluster. The cluster one is more associated with proportion of beer banana sold, proportion of land allocated to beer banana and proportion of beer banana consumed as highlighted in the table thus they are named Beer Banana

Farmers (BBF). The second cluster which is more associated with tropical livestock unit (Livestock numbers converted to a common unit), education years and nutrition diversity is named Livestock Based Farmers (LBF) whereas the third cluster named Cooking Banana Farmers (CBF) is more associated with proportion of land allocated to cooking banana and proportion of cooking banana sold and consumed.

Table 19: Variables responsible for farm heterogeneity and resulting clusters

Variable	V.test Mean C1	V.test Mean C2	V.test Mean C3
Nutrition Diversity	-5.12	**2.55**	2.89
Extension number	-2.02	**-**	-
Education Years	-3.10	**2.91**	-
Tropical Livestock Unit	-2.56	**3.38**	-
Cooking Banana Land P.	-11.20	-8.38	**20.62**
Cooking Banana P. Consumed	-9.13	-7.81	**17.81**
Cooking Banana P. Sold	-9.60	-8.26	**18.78**
Beer Banana Land P.	**16.77**	-12.41	-5.30
Beer Banana P. Consumed	**6.39**	-5.60	-
Beer Banana P. Sold	**19.45**	-14.27	-6.27
Banana income	-	-4.94	5.77
People talked to	-4.15	-	3.95
Named according to V.test	***Beer Banana farmers(BB)***	***Livestock based farmers(LB)***	***Cooking Banana farmers(CB)***

Characteristics of respondents by clusters

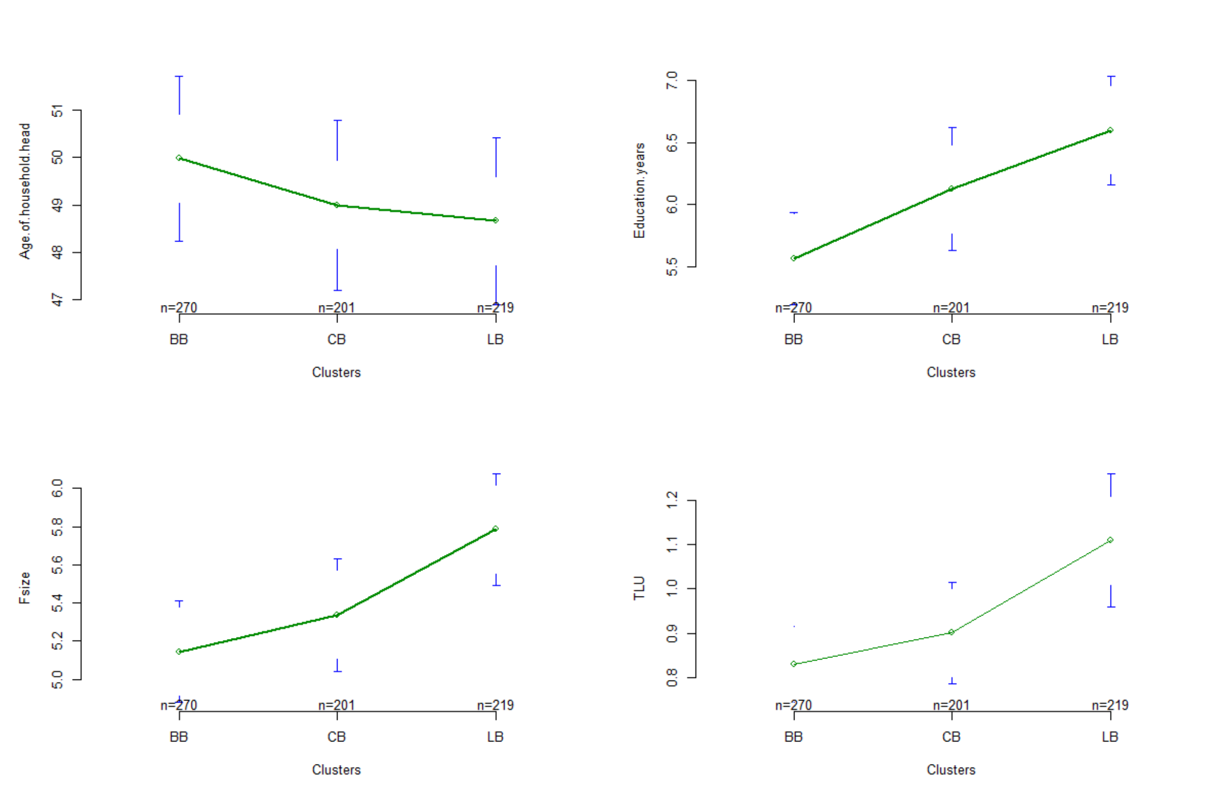
Table 2 presents characteristics of household and respondent by banana farm clusters in terms of gender and farm experience in BXW infection. Majority of respondents (57.8%-64.4%) were males but the difference was very high in livestock based farmers. There was no significant difference between typologies in terms of having experienced or experiencing BXW (Table 5) suggesting that they are all equally vulnerable.

Table 20: Descriptive statistics characterizing household and respondent by banana farm clusters

Variable	Category	Beer BF(270)	Livestock BF(219)	Cooking BF(201)	χ2tests of independence
Gender of respondents	Female(276)	(114)42.2%	(78)35.6%	(84)41.8%	$\chi 2(2)= 2.58$ NS
	Male(414)	(156)57.8%	(141)64.4%	(117)58.2%	

Experienced BXW	No(225)	(98)36.3 %	(64)29.2%	(63)31.3%	χ2(2)= 2.96 NS
	Yes(465)	(172)63.7%	(155)70.8%	(138)68.7%	

The figure 3 summarizes means of quantitative variables characterizing respondents by clusters. The average age of beer banana farmers (49.9±14.8 years) was slightly higher than the rest of banana farmers. The livestock based farmers were significantly highly educated (6.6±3.3 years of education) than other groups. The average family size and tropical livestock unit was higher for livestock based farmers while cooking banana farmers had higher banana income (15.4±41.0*10000 Rwandan Francs) and proportion of cooking banana sold. Concerning the average number of people talked to, an indication of information exchange regarding BXW management, cooking banana farmers had high average number (18±46 people).



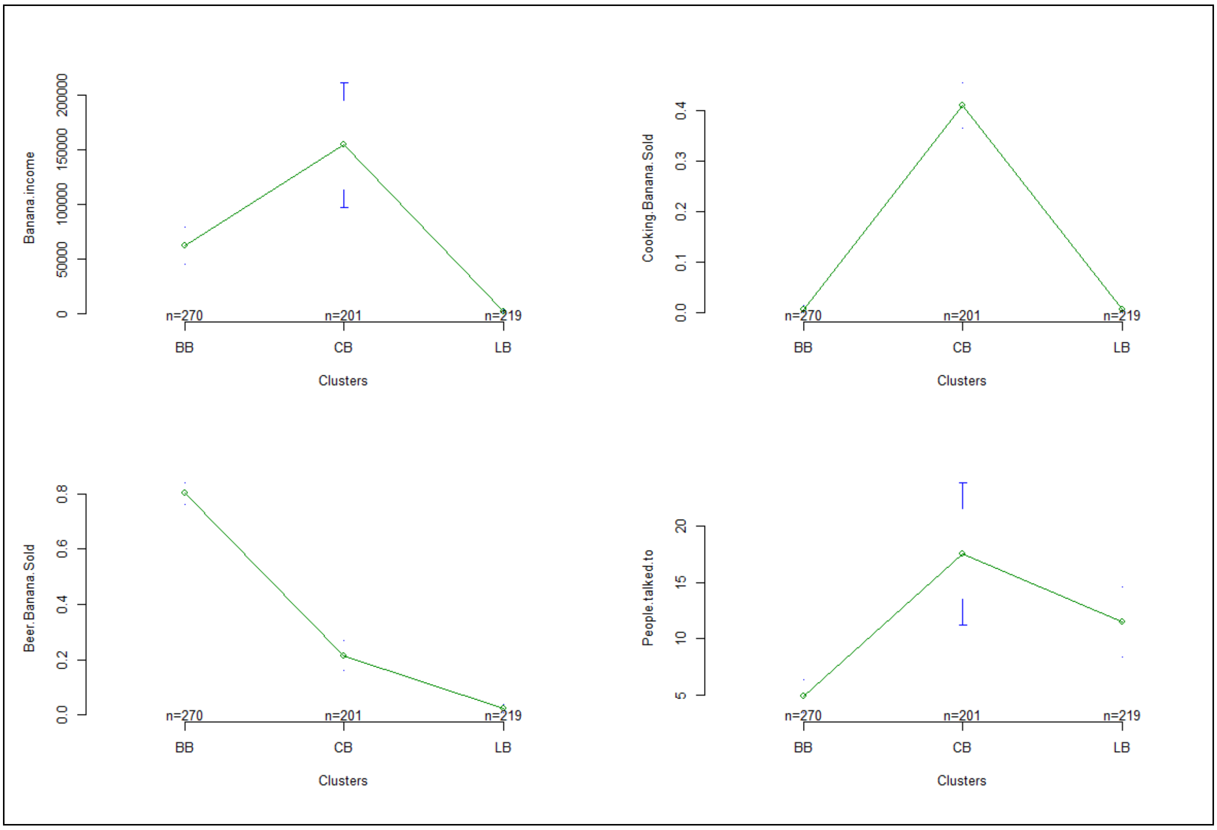


Figure 37: Characteristics of household and respondent by banana farm clusters

Implications of farmer typology for ICT use

In results presented in table 3 and 4 cooking banana farmers are used as reference in the logistic regression analysis. Results presented in table 3 show that cooking banana farmers are more likely to own both smart and basic phones. Beer banana farmers had significant decreasing likelihood of owning and use mobile phone both smart and basic compared to cooking banana farmers. Furthermore beer banana farmers had also more than two times higher likelihood of not having mobile phones. Although livestock banana farmers had a dicreasing likelihood about owning and using both smart and basic mobile phones this was not significant compared to cooking banana farmers.

Table 3: Regression analysis results about clusters ownership and use of mobile phones

Response variable	Predictor variable	Coefficient	S.E.	p-value	Odds ratio
Own smart phone	Banana grower cluster			0.059	
	Beer BF	-1.0	0.5	0.044*	0.4
	Livestock BF	-1.0	0.5	0.065	0.4
	Constant	-2.8	0.3	0.000***	0.1
Own basic phone	Banana grower cluster			0.001***	
	Beer BF	-0.7	0.2	0.001***	0.5
	Livestock BF	-0.2	0.2	0.314	0.8
	Constant	1.3	0.2	0.000***	3.7
Does not own a phone	Banana grower cluster			0.001***	
	Beer BF	0.8	0.2	0.000***	2.3
	Livestock BF	0.4	0.2	0.132	1.4
	Constant	-1.4	0.2	0.000***	0.2
Used smartphone	Banana grower cluster			0.009**	
	Beer BF	-1.6	0.6	0.005**	0.2
	Livestock BF	-1.0	0.5	0.050	0.4
	Constant	-2.6	0.3	0.000***	0.1
Used basic phone	Banana grower cluster			0.001***	
	Beer BF	-0.8	0.2	0.001***	0.4
	Livestock BF	-0.3	0.3	0.279	0.7
	Constant	1.8	0.2	0.000***	6.2

Key: *BF= Banana farmers, S.E=Sandard error*

ICT use barriers

Results presented in table 4 show that cooking banana farmers had no significant particular barriers in the provided list however they are more likely to face other challenges which include the fact that ICT-based tools are expensive, language barriers, etc. Beer banana farmers are more likely to lack awareness of the existence of mobile based extension services than others and are also two times more likely to lack technical know how to use phone based extension services. Livestock banana farmers, though having positive likelihood of facing barriers such as awareness, availability and lack of technical Know how, these were not significant compared to cooking banana farmers.

Table 4: Regression analysis results about clusters ICT use barriers

Barriers to the use of ICT	Predictor variable	Coefficient	S.E.	p-value	Odds ratio
Awareness	Banana grower cluster			0.074	
	Beer BF	0.4	0.2	0.029*	1.5
	Livestock BF	0.1	0.2	0.544	1.1
	Constant	-0.1	0.1	0.438	0.9
Availability	Banana grower cluster			0.544	
	Beer BF	0.4	0.4	0.435	1.4
	Livestock BF	0.5	0.5	0.272	1.6
	Constant	-3.2	0.4	0.000***	0.0
Know how	Banana grower cluster			0.079	
	Beer BF	0.4	0.2	0.027*	1.5
	Livestock BF	0.2	0.2	0.361	1.2
	Constant	-0.8	0.2	0.000***	0.5
Time	Banana grower cluster			0.321	
	Beer BF	0.2	0.5	0.741	1.2
	Livestock BF	0.6	0.5	0.178	1.9
	Constant	-3.3	0.4	0.000***	0.0
Language	Banana grower cluster			0.743	
	Beer BF	-0.3	0.5	0.523	0.7
	Livestock BF	-0.4	0.5	0.495	0.7
	Constant	-3.1	0.3	0.000***	0.0
Literacy	Banana grower cluster			0.533	
	Beer BF	0.5	0.4	0.271	1.6
	Livestock BF	0.2	0.5	0.608	1.3
	Constant	-3.2	0.4	0.000***	0.0
Others	Banana grower cluster			0.026*	
	Beer BF	-0.7	0.2	0.007**	0.5
	Livestock BF	-0.4	0.2	0.125	0.7
	Constant	-1.2	0.2	0.000***	0.3

Key: *BF= Banana farmers, S.E=Sandard error*

The table 5, containing summary of descriptive statistics about farmer's perception about the use of ICT (Mobile based) BXW management practices information delivery, shows that majority of respondents, in all banana farm clusters, perceived the use ICT-based agricultural services as somewhat useful but beer banana farmers had big number of farmers perceiving the ICT-based agricultural services as irrelevant.

Table 5: Relevance of ICT for BXW management by clusters

ICT relevance Category	Beer BF(270)	Livestock BF(219)	Cooking BF(201)	χ2tests of independence
Neutral(79)	(40)14.8%	(30)13.7%	(9)4.5%	$\chi2(2)= 25.57^{**}$
Not useful(24)	(13)4.8%	(2)0.9%	(9)4.5%	
Somewhat un-useful (123)	(46)17%	(32)14.6%	(45)22.4%	
Somewhat useful(368)	(134)49.6%	(129)58.9 %	(105)52.2%	
Very useful(96)	(37)13.7%	(26)11.9%	(33)16.4%	

DISCUSSION

The use of ICT in agriculture is considered as a key pillar of Rwandan economic transformation towards middle income country (Lichtenstein, 2016). According to Salampasis and Theodoridis (2013) an ICT tool is defined an application or a device used to collect and exchange data through interaction or transmission. In this study we evaluated the potential of using phone based extension services for effective BXW management. From this reason we analyzed baseline study survey data to understand how ready farmers are in this regard. In addition to this, to facilitate effective intervention tailoring, we considered farm heterogeneities by grouping them into clusters of similar socio-economic characteristics. It has been discussed that the limited adoption of innovation is probably associated by using a one-size-fits-all model (Coe et al., 2016; Hammond et al., 2017).

The PCA identified 12 variables responsible for banana farmers' heterogeneity which were used in farm clustering. The identified farm clusters, zooming in the main focus of farm banana production system, seemed to be appropriate and meaningful in Rwandan banana farming system. The main focus of first cluster (BBF) is the beer banana which is allocated to a large portion of banana land, the second cluster (LBF) main focus is livestock whereas the third cluster (CBF) main focus is cooking banana also allocated to a large portion of banana land. As discussed by Bidogeza et al. (2009) results from clustering must be clear and realistic to represent the empirical situation. Several studies emphasized that clustering individuals in more similar characteristics group is a potential entry point to diffusion of innovation and uptake since this probably results in almost similar behaviors (Bidogeza et al., 2009; Blazy et al., 2009; Barnes et al., 2011; Hammond et al., 2017). With results of this study we believe that the main focus of a farm cluster is also the priority of that farm thus any intervention plan should take this into account. For example, in the context of BXW prevention and control, animals have significant implications (Nankinga and Okasaai, 2006; Tinzaara et al., 2011). In this regards BXW interventions design for livestock based farmers should consider that the group might consider that animals are more important than banana. In line with arguments of Janssen et al. (2017) that for the community to benefit from ICT based model they should be involved in co-development to cover priority needs of beneficiaries, we argue that developing a phone based application to manage BXW in banana production system, for example, should consider to include in some ways livestock management options for the sake of livestock based farmers. This support the theory of diffusion of innovations by Rogers (2003) mostly the point that innovation is quickly adopted when it fits in the existing social values and practices.

Concerning banana farm clusters owning and using mobile phone, the different groups have varying likelihood to own and use mobile devices. The cooking banana farmers seemed to be better-off in view of banana income possibly reason why they are more likely to own and use mobile phones. This is in agreement with the study by Tadesse and Bahiigwa (2015) who studied the impact of using mobile phones in agricultural marketing in Ethiopia. Majority of farmers had basic type of mobile phones which has implications on the potential of using agricultural mobile application as most of applications are designed to be used in smart phones. The study by Tadesse and Bahiigwa (2015) identified age and education level as significant determinants of owning and using a mobile phone where younger are more likely to own and use the phone and higher education increases the probability. This is in slight agreement with our findings since the average age of beer banana farmers who are less likely to own and use phones is high and the cooking banana farmers who are more likely to own and use phones had higher education level compared to other group of farmers. In regards of McCampbell et al. (2018) review suggesting four pathways of using ICT (Mobile phone) based extension services to prevent BXW occurrence we assume that smart phone owners, in the case of this study cooking banana farmers, have a lot more ways to provide information back, but for normal phone users (Beer banana farmers) this use is limited. However there are also a number of ways that basic phones can be used to provide farmers with information and learning tools such as SMS and voice based. From this respect cooking banana farmers and livestock banana farmers are more likely to be open for providing data for prevention and sharing/receiving technical information for control whereas beer banana farmers can also be connected for connective actions.

The main challenge of the use of ICT (Mobile phone) based extension services was lack awareness of the existence of such services and the limited technical know-how. This implies that the release of mobile based application will requires sensitization for raising awareness especially to beer banana farmers who are more likely to face these challenges than the rest of banana farmers groups. Awareness, technical know-how and availability of services are important variables that influence adoption, perception and use of ICT based solutions.

CONCLUSION AND RECOMMENDATIONS

Results show that cooking banana farmers are more likely to have and use mobile phones both smarts and basics than other banana growers' clusters. Beer banana farmers have higher likelihood of not having a phone and have big number of farmers perceiving the ICT for BXW management as irrelevant. The use of ICT is limited by lack of awareness and lack of technical knowhow in beer banana farmers whereas cooking banana farmers are limited by other challenges such as being expensive. The studied farmers provide potential for using ICT (Mobile based) extension services however beer banana farmers, less likely to own smart phones, are limited to few options. We conclude that the use and perception of phone based extension delivery is differentiated by banana production system described as farm clusters in this study and major barriers to "use and perception of phone based extension services" is associated with limited access and linkage to extension delivery system. We thus recommend the consideration of heterogeneity of banana growers when designing and deploying ICT based technologies to prevent and control BXW.

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IS FARMING TECHNOLOGY INNOVATION LOCUS DEPENDENT? MAKING-OF AN AGRICULTURAL FABLAB

Davide Rizzo[a,b], Anne Combaud[a], Nathalie Schnuriger[c], Fatma Fourati-Jamoussi[a], Simon Ritz[b], Valérie Leroux[a]

[a] InTerACT Research Unit UP 2018.C102, Institut Polytechnique UniLaSalle, France
[b] Chair in Agricultural Machinery and New Technologies, Institut Polytechnique UniLaSalle, France
[c] Institut Polytechnique UniLaSalle, France

Abstract

Innovation has multiple targets – products, production processes, marketing, stakeholders' organizations, etc. – whose nature depends upon the socio-technical framework that orients the match between inventions and market. Amid the wealth of options to facilitate innovation, fablabs are a specific example of the digitalisation era. Originally, a fablab is "the educational outreach component of MIT's Center for Bits and Atoms" whose identity is defined by a charter that connects local labs to the global network. Fablabs' goal is to provide stimulus for local entrepreneurship as well as for learning and innovation by providing access to tools for digital fabrication. This paper aims at understanding the role of fablabs and other third places in the specific context of farming technology innovation. To this end, we propose a genetic-like analysis (i.e. genotype x environment x management practices), by addressing the historical identity and traits of FTI actors, the description of the main characteristics and dynamics of the place where they are based and the innovation governance put in practice to enhance their interactions. The approach was applied at two levels: first, the main actors of the farming technology innovation in Europe, ending with a bibliometric analysis of the available literature about fablabs, makerspaces and living labs, with a focus on agriculture. Then, a case study from northern France to describe the making of AgriLab, a fablab dedicated to open innovation towards sustainable agriculture, spanning from equipment to digital tools. AgriLab is based in Beauvais (Hauts-de-France region), together with several other local and international actors of farming technology innovation. In conclusion, we question the role of third places and AgriLab as catalysts for the emergence of relevant farming technology innovations considering the influence from the local and wider context.

Introduction

Innovation is a novelty introduced within an established arrangement, according to the Latin etymology. Accordingly, the farming technology innovation (FTI hereafter) could be referred to the novelties introduced in some of the established ways of farming, namely concerning the tools mobilised to accomplish agricultural practices. Of notice, we adopt here a wide concept of innovation, which embraces novelties in production assets, production processes, products, marketing, stakeholders' organization and so forth.

Our main question is: how are farmers involved in FTI? The underpinning hypothesis is that future FTI needs to identify approaches to empower farmers innovation capabilities within the farming 4.0 ecosystem (Dubois et al., 2019). We adopted a broadly interpretivist approach inspired by a genetic-like framework, where the observed features are considered as a result of the interaction between genotype x environment x management practices. This metaphor was meant to address the interactions between the history of involved actors (the genotype) and their place-related features (the environment) as a way for evaluating and orienting the innovation governance (management practices). In this vein, we stressed the role of support space (the locus) in forging the innovation system. Of notice, we consider that actors' location is a key factor in orienting FTI because of the place-based nature of agriculture.

Indeed, agriculture is by its nature deeply related to the given agronomical and pedoclimatic context where it is operated (van Ittersum and Rabbinge, 1997). In this sense, farmers are entrepreneurs whose knowledge is rooted in the daily management decisions about crop and animal husbandry. In the progress from the second to the third agricultural revolution, farmers benefited of a greater technology transfer from research and industrial development; yet, they became more dependent from external actors for the provision of productions assets like genetic improvement, phytochemicals and mechanics. Digitalization is at the origin of a fourth revolution in agriculture by adding a non-tangible dimension to the production assets. In the "farming 4.0", or augmented agriculture, a brand-new cyber-physical frontier can be used to extract data and information from farmers' practices and the agricultural production system (Lioutas et al., 2019), finally allowing a knowledge intensive agriculture.

The aim of this paper is to describe the making of a fablab explicitly oriented to farmers, called AgriLab emerged within an agricultural socio-technical system in northern France. We applied the interpretative framework to two embedded levels of FTI. In the first section we address the agricultural digital transition in Europe; in the second section we focus on northern France, as one of the regions with the highest arable land ratio within the first European country for agricultural production (Agreste, 2018). In particular, we explored how the anchorage of an agtech cluster within a field crop farming system region could enhance farmers involvement in FTI. Each section is structured in three parts: (1) identification and brief history – the *genotype* – of the main FTI actors; (2) highlight of the context and place (i.e., *locus*) dependent features, interpreted as the effect of the *environment*; (3) emergence of third places in the FTI governance, interpreted as the *management practices* that could help understanding the expression of locus dependent features.

Third places indicate hereby the physical spaces where new product development can take place. Their specificity is being sites (i.e., *loci*) emerged to meet the expectations of heterogeneous actors towards emancipation and community empowerment (Rosa et al., 2017). Generally identified as places for the "maker movement", they can also emerge to enable creativity within established corporate actors thanks to the reset of organizational boundaries (Fuller and David, 2017). Our focus will be on fablabs and maker spaces, as the wider context of emergence of two agricultural specific third places, like FarmHack in the USA and Atelier Paysan in France.

Altogether, the descriptions will set up the background to analyse the emergence of an agricultural fablab as a third place between farmers and the others actors involved in the FTI. In conclusion, we propose some considerations about the levers to enable the role of AgriLab as catalyst in the emergence of relevant (digital) technologies for sustainable agriculture within the agricultural innovation ecosystem.

First level: FTI within agricultural digital transition in Europe

In a world perspective, European agriculture is characterized by great attention to precision and data augmented agriculture (Kritikos, 2017; Schulze-Lammers et al., 2016). As such, the equipment sector being reshaped by the arrival of many newcomers and agtech provides that are external both to the manufacturer and the agricultural domain (Rizzo et al., under review). For the first level of description of the FTI, we focused on European actors of the crop production, the farming 4.0 context and a rapid overview of innovation governance through fablabs and similar "third places".

Main actors of FTI in Europe (genotype)

Mechanization is one of the drivers of the third agricultural revolution, being so far an important arena for the emergence and development of FTI. The agricultural machinery sector is composed by manufacturers, dealers and the different users, including farmers, their groups and cooperatives as well as contractors (Rizzo et al., under review).

Machinery manufacturers include the constructors of machines (e.g., tractors, seeders, harvesters), and tools (e.g., ploughs, harrows) that can be used for realizing farming practices. They have historically evolved from blacksmith workshops, gradually joined with the availability of mechanical engines. As such, these manufacturers master metals and materials needed for the manufacturing, as well as the practical skills to shape tools suited for farming. Manufacturers include different sizes and profiles of enterprises, from the small and medium ones, frequently specialised in a few types of equipment, up to large enterprises, for the most correspondent to international groups that produce all the equipment needed from the soil preparation to harvesting. Manufacturers pointed-out the weakening of the interfaces with the end-users, namely the farmers, because of the decrease in the number of farms so of clients (Dryancour, 2016). Moreover, the digitalization and shift towards augmented agriculture widened the concept and development of equipment, eventually including embedded sensors and electronic connection on-board. This resulted in the emergence of new actors, either as technology or machine provides, such in the case of ISOBUS and agricultural robots.

Dealers. The growing specialization and outreach of the machinery market needed the organization of distribution and selling. As so, the machinery dealers represent for manufacturers the real interface with final users. The restructuration of the machinery sector due to the reduction in the number of farmers is stressing the competition between brands and associated dealers (Dryancour, 2016). This results in a profound revision of the distribution strategy, leading on the one hand to merging selling points and on the other hand to the differentiation of services. In particular, the dealers claim a role in the development and provision of new data-related services for the farmers (CLIMMAR, 2018), which are on their side relying on dealers to be supported in the choice of agtech. A survey carried out in 2019 in France involving 952 farmers and 112 contractors showed that 3 respondents out of 4 believe that dealers will be the best actors to buy agtech from (Enquête Datagri, 2019).

Farmers represented roughly 4.4% of the working population across the European Union in 2015, accounting for 10 million people (Eurostat, 2017). They are organised in the Copa-Cogeca group of interest. In a recent document, they wrote in their strategy the call to facilitate the technological uptake through training and advisory services; also, they stressed the belief in farmer-led agri-tech revolution and the role of cooperatives for driving the digital transformation of the sector (Copa-Cogeca, 2019).

FTI under farming 4.0 (environment)

The increasing number of connected devices and embedded sensors are allowing for the digitalization of physical variables, as well as to tracking farmers' actions. Altogether, the availability of a growing amount of very diverse data, together with the progress of computational capabilities, is enabling the development of advanced algorithm capable to extract relevant knowledge from complex systems. Devices, data and computational capabilities are eventually paving the way for new deep insights in farmers' decision-making process. In summary, where the third agricultural revolution reduced the farmers' mastery of production assets, the fourth one could increase the dependence of farmers from external actors, namely the digitalization players, up to the extraction of farmers' tacit knowledge codified in algorithms and decision support systems (Dubois et al., 2019).

In this perspective, we argue the risk for FTI to leave farmers apart from the definition of relevant novelties for their entrepreneurial activities. Insofar, a rich literature addressed the adoption of FTI by farmers, eventually considering them as the passive recipients of accomplished solutions. A different perspective could emerge if looking at the reasons of the actual use of FTI, such as precision farming techniques. A pioneering study about how technologies were used by adopters pointed-out the need for local references to evaluate the on-farm relevance of such innovations (Ayerdi Gotor et al., 2019). Furthermore, the non-tangibility that characterizes the digital components of the farming 4.0 FTI raises questions about knowledge disparities and trust among actors (InPACT, 2016; Jakku et al., 2018).

Third places for innovation governance (management)

The maker movement is resulting in the emergence of dedicates places, which take different names according to the way the community is ruled. We performed a bibliometric analysis to set the scene about the three most accepted definitions of third places: fablabs, makerspaces and living labs. To this end, we retrieved three corpora on the Scopus database (Table 21). The results were heterogeneous both for the number of retrieved items and for the covered period, probably because of the level of specificity of each definition and for its age of use (Figure 38). On the one hand, living lab appears to be the most generic and long used of the three, even though only a few items were retrieved before 2004. On the other hand, fablab and makerspace could have a partial, though limited, overlap; the latter definition emerged in the scientific literature probably as more generic version of the MIT version and related to the Maker Faire concept as social event to gather together different "makers" (Rosa et al., 2017).

Table 21. Constitution of the corpora for the bibliometric analysis of fablab and maker space literature.

Corpus [a]	Search string [c]	Nb of items	Period
FL – fablab [b]	(TITLE-ABS-KEY (fablab*) OR TITLE-ABS-KEY ("fab lab")) AND PUBYEAR > 2001	312	2004-2020
MS – makerspace	(TITLE-ABS-KEY (makerspace*)) OR (TITLE-ABS-KEY ("maker space"))	598	2010-2020
FL-MS (items mentioning both)	((TITLE-ABS-KEY (fablab*) OR TITLE-ABS-KEY ("fablab")) AND PUBYEAR > 2001) AND ((TITLE-ABS-KEY (makerspace*)) OR (TITLE-ABS-KEY ("maker space")))	65	2012-2019
LL – living lab	(TITLE-ABS-KEY (livinglab*)) OR (TITLE-ABS-KEY ("living lab"))	1413	1990-2020

[a] research performed on November 3rd, 2019 on the Scopus database in title, abstract and keywords
[b] the research aimed at simple and plural occurrences of the search terms
[c] the first Fablab was established by MIT in 2002, so the research was limited to paper after 2001.

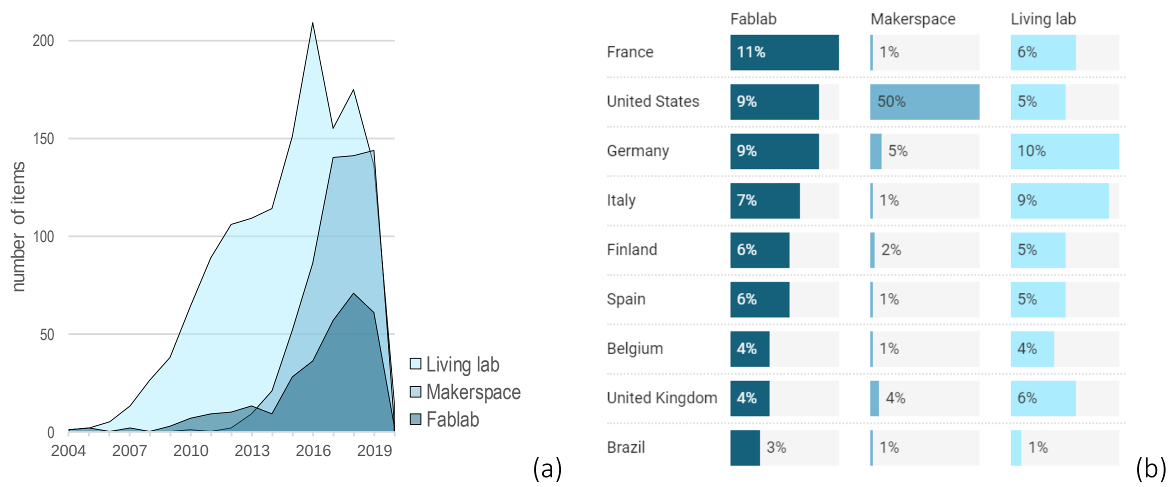

Figure 38. Quantitative description of the three corpora: fablab, makerspace and living lab. (a) number of published item per year, subset from 2004 to 2020; (b) distribution of affiliation countries, percentage on the total number of affiliations per corpus, subset oft he 9 top countries for fablab literature (source: elaboration on Scopus corpora).

Living lab overall idea is credited to the early 2000s by the Massachusetts Institute of Technology. The scientific literature about living lab is continuously growing from 2006 (Figure 38, a), year of publication of the Helsinki Manifesto. It was issued from a conference that "proposed renewal of the European innovation system to create a new open, user-centric and networked innovation environment in Europe” (Finland’s EU Presidency, 2006) The same conference led to the creation of the European Network of Living Labs as the international federation of benchmarked Living Labs in Europe and worldwide. The year 2016 marked an important step in this network with 7 new approved EU projects and 7 that were successfully concluded (ENoLL, 2018). Altogether, living lab identified an approach to open innovation focused on citizens involvement and a focus on public-private partnerships, eventually allowing for a better understanding and elicitation of the ontology of the needs (Dutilleul et al., 2010). As such, living lab embraces also more defined approach such as fablabs and makerspaces and the like (Givone et al., 2015).

Amid the wealth of options to facilitate innovation and living lab forms, fablabs are a specific example of the digitalisation era, which is focused on the connection between bits and atoms. Indeed, fablab (shorter for Fabrication Laboratories) is “the educational outreach component of MIT’s Center for Bits and Atoms” whose identity is defined by a charter that connects local labs to the global network. Complying with the Fab Charter (CBA, 2012) is a distinctive feature of fablabs, which should provide a core selection of hardware and software capabilities allowing to reproduce projects across the community network (Rosa et al., 2017). Fablabs’ goal is to provide stimulus for local entrepreneurship as well as for learning and innovation by providing access to tools for digital fabrication. The retrieved literature about fablab appears to be lower than the other two corpora, though revitalized after 2016 (Figure 38, a).

Makerspaces are grassroots “community centres with tools” (Gui Cavalcanti, 2013) framed within the do-it-yourself and maker movement, in large parts oriented by pragmatism and a continuous problem-driven exchange within the community (Voigt et al., 2016). Makerspace definition stemmed out of the hacker community (Marusteru, 2017), yet clearly defined only on 2013 for a workshop called “How To Make A Makerspace” (Artisan’s Asylum and MAKE, 2013). This concept showed then a steady increase in the literature (Figure 38, a).

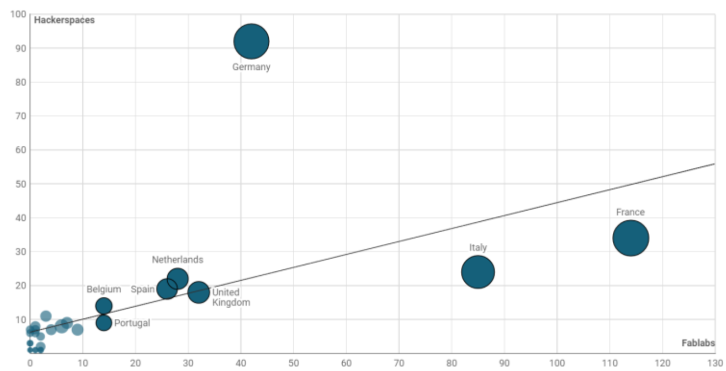

Figure 39. Number of makerspaces in Europe, according to their type. Adapted from the survey by Rosa et al. (2017). Dot size is proportional to the total number of spaces, including fablabs, hackerspaces and other types (the latter are not shown). The trend line separates countries according to the dominant type of space: hackerspaces in the upper half, fablabs in the lower half.

The three corpora showed a clear territorial anchorage, with publications about fablabs coming chiefly from researchers affiliated in France (11% of the total affiliations of this corpus), makerspaces from the United States (50% of the corpus) and living lab from Germany and other European countries (Figure 38, b). This could suggest a linguistic differentiation in reference to similar approaches and concepts that is consistent with the trends in Google search (Voigt et al., 2016)[101]. A recent European report surveyed fablabs, hackerspaces and other types of what they called collectively “makerspaces”, showing that France, Germany and Italy have the greatest number of these spaces, yet with a different distribution (Figure 39).

[101] Cf. https://trends.google.com/trends/explore?date=all&q=makerspace,fab%20lab,hackerspace,living%20lab

The corpora were analysed with the CorText platform (http://www.cortext.net) to get a rapid simple overview of the key terms, the structuring topics and the interest per Country (i.e., the affiliation country of the authors of the retrieved item). We processed the corpora to extract the terms through a text mining script operating a natural language processing. This allowed us to go beyond the too synthetic topic description provided through author keywords, by including also title and abstract per each retrieved item.

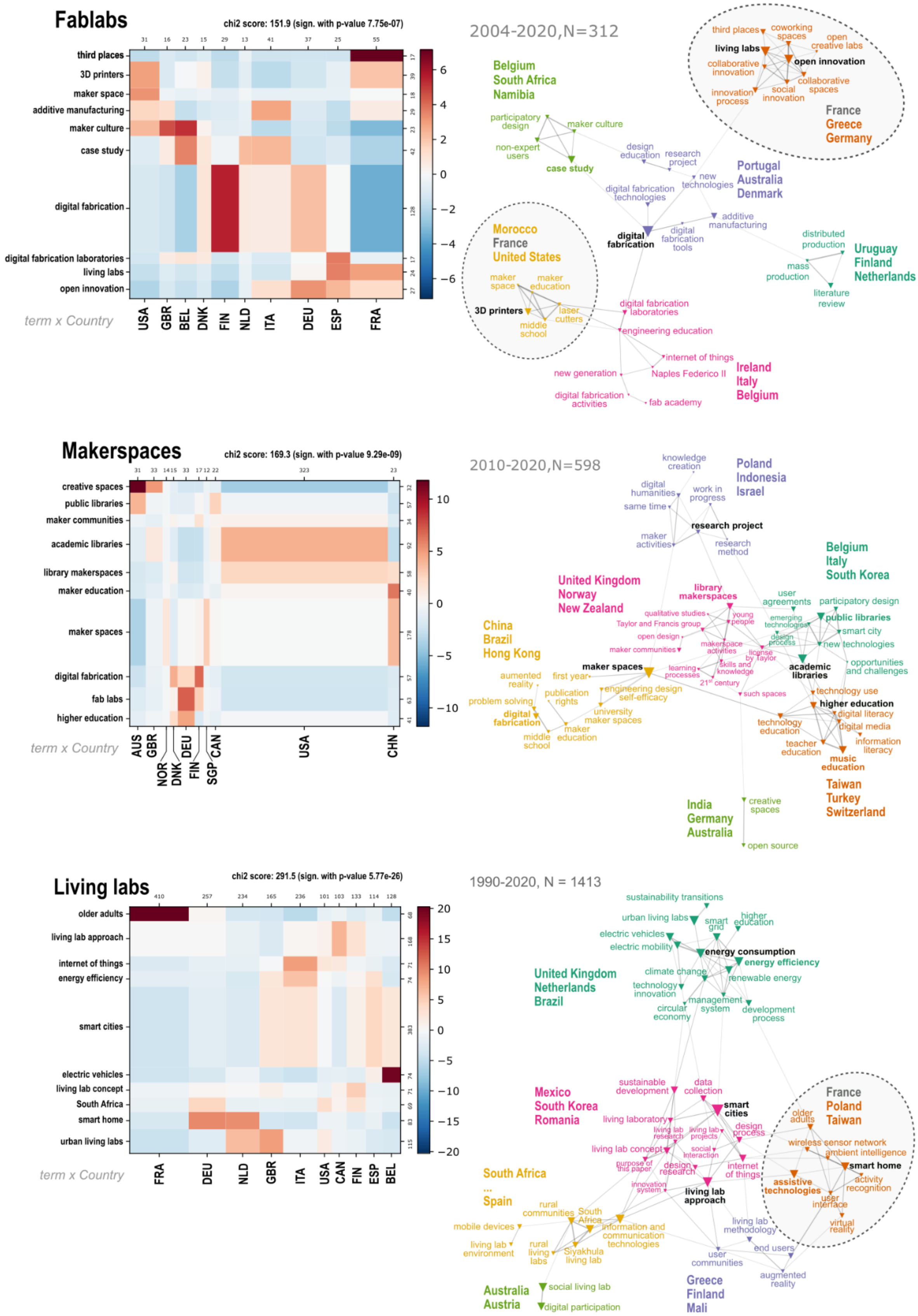

Figure 40. Bibliometric analysis of terms and Countries of researchers' affiliation. (left) Contingency matrix showing the degree of correlation between the 10 top pairs of term-Country. The size of the squares is proportional to the term frequency in the database. Cell colour refers to the significance of

the correlation, red for the most correlated (co-occurrence higher than expected), blue for the anti-correlated (co-occurrence lower than expected), while the intensity of the colour represents the chi2 score of relevance. (right) Terms co-occurrence base on the top 50 nodes. The triangles represent individual terms and their size is based on the number of co-occurrences. Colours of the triangles identify clusters of co-occurrent terms, then labelled by the authors' affiliation country, with proximity meaning terms mention by authors whose affiliation is in the same countries (France in shaded circles).

The script for term extraction follows 5 steps: identification of the part of the speech (noun, adjective, verb, etc.), chinking to build possible multi-terms (e.g., a list of successive nouns), normalization to smooth minimal orthographical differences (e.g., grouping of hyphenated and non-hyphenated forms), stemming to group terms that share the same root, then counting (Cortext team, 2016). Based on the extracted terms, we performed two analyses: (1) *contingency matrix* to compare the frequency of term per Country; (2) *term co-occurrence* graph to map proximity between terms, then clustered and labelled by country (Figure 40).

Concerning fablabs, the results highlighted a significant positive occurrence of the terms "third places" and "living labs" in the documents by French researchers, who are less inclined at referring to "digital fabrication" and "maker culture". The latter are more frequently used, respectively by Finnish or Belgian researchers, who appeared oriented also towards distributed production, internet of things and fab academy. Makerspace literature resulted in a more compact configuration as it is more recent. Of notice, researchers from Australia emphasized the association with "creative spaces", whereas Germany and Finland were more oriented to fablabs and, again, digital fabrication. In conclusion, living labs were chiefly associated to older adults by French researcher and electric vehicles from Belgian (Figure 40).

In this rapidly evolving landscape, the European Union drew a first census of makerspaces (including though hackerspaces and fablabs), counting a few hundred of different spaces, for the most located in France (158, 114 of which fablabs), Germany and Italy (Rosa et al., 2017). Some of them can declare a thematic orientation, for instance to reduce concurrence in areas where multiple close communities coexist; though, the basic idea is that the identity of these labs and spaces is foremost defined by the community and not simply as physical equipped sites. Indeed, only few if none of the labs or spaces is specifically dedicated to agriculture. Some of the reasons can be the anchorage within city-based communities and the lack of space. Agriculture is therefore addressed as urban agriculture, even though a few exceptions exist. FarmHack and Atelier Paysan are among the oldest. Farm Hack was founded in 2010. It is an on-line and in-person community of farmers, engineers, and technologists working to make farm tools and equipment more accessible, adaptable, and appropriate to small and medium scale sustainable agriculture systems (Cox and Grover, 2015). Atelier paysan is a French community that presents itself as a cooperative for auto-construction of agricultural equipment, formalized in 2011. They stress the farmers' capability to invent the tools needed for farming. Both of these communities foster to put full control over the means of production into the hands of farmers as a mean to empower peasants and pursue sovereignty for collective food security (Pimbert, 2017).

Second level: FTI in the case study (Beauvais, northern France)

For the second level, we focused on France and the FTI actors located in Haut-de-France region (northern France), with a focus on the Beauvais area for its concentration of FTI actors (Rizzo et al., 2018). In particular, we stressed the history of the actors involved in the development of agricultural machinery and software, as well as in education. The choice of the regional and local administrative bodies to enhancing connections and alignment between actors in innovation systems by strengthening the public/private/people partnership (cf. Hermans et al., 2019). We analyze here the results of major local innovation governance measures that led to the emergence of third places both within the enterprises, the academy and independent (for this classification, cf. Bouquin et al., 2016), as well as new actors. The main question is the explicit involvement of farmers as actors in FTI.

Local actors of FTI: history and interactions (genotype)

(1854) Institut Polytechnique UniLaSalle. It is a higher education institute that proposes, on Beauvais campus, short programs and degrees in agriculture, geology and food and health (www.unilasalle.fr). In its earlier form, it dates back to 1854 as section in the local school for teachers. Since the earlier years, founders fostered the relation practice-theory-practice and addressed the synergies between agricultural and industrial sectors as main drivers of the national development. Accordingly, the educational program included the purchase of a farm and the creation of experimental stations, and it is nowadays strongly committed to the integration of sustainability in the educational programs (Fourati-Jamoussi et al., 2018). Throughout its history, two societies of software development stemmed out: (i) ESCORT, based on a study office created in 1969; (ii) ISAGRI, created as a spin-off in 1983 (see below).

(1960) AGCO. Massey-Ferguson sided its production sites of Banner-Lane in Coventry with a new plant in Beauvais, where the tractor produced in Saint-Dizier were assembled. This manufacturer was the third in Europe, and the third in the world since the acquisition by the AGCO in 1994. The Coventry site that was dismissed in 2003 was the largest tractor manufacturer facility in the western world. The move to northern France was initially justified by the lower operational costs, then confirmed for the location within a well-known agricultural production context (Bienfait, 1959). As such, the site continues to develop the territorial anchorage (Desindes, 2012): three additional production sites have been implanted in Beauvais, the fourth having been bought in 2019. Leader for standard tractor production in France, Massey-Ferguson Beauvais is the most important AGCO production facility in Europe (Jouan and Paturel, 2019). By the way, AGCO started interactions with UniLaSalle, by becoming a partner for the provision of tractors and combine to its farm, and lately, a supporter of the Chair in agricultural machinery (see below). Also, its current vice president & managing director for Europe and the Middle East, Thierry Lhotte, is an UniLaSalle alumni.

(1994) Groupement International De Mecanique Agricole - GIMA. In 1994, Massey Ferguson created, before its integration in AGCO group, GIMA, a joint venture (60:40) with Renault agriculture, later become CLAAS tractor. The goal is to develop and produce transaxles systems for agricultural application. GIMA is an important asset to strengthen the industrial development of Massey-Ferguson.

(1983) Groupe-ISA. The group consists of ISAGRI, Irium Software and Nouvelle génération de presse agricole. Irium SOFTWARE is the European leader of Enterprise Resource Planning for agricultural machinery (dealers, rentals, importers...). Nouvelle génération de presse agricole is a media group, leader in the agricultural field, included printed press, website and a society of analysis and understanding of farmers' behaviors and expectations. ISAGRI is a European leader in the development of computer-based tools for farm management. It was created by a teacher of the Agricultural Engineer School of Beauvais, Jean-Marie Savalle, current CEO, and a few colleagues. In 1995 they left the school buildings where the spin-off was born yet remaining in the neighbouring area to keep the proximity and ease the students' recruitment. Every year, ISAGRI organizes a vocational training week for its employees on the UniLaSalle Beauvais campus. In 2019, ISAGRI signed a convention on disability with UniLaSalle in 2019 to facilitate the inclusion of students with disabilities

Cumulatively, in 2017 these actors employ almost 3,500 people (i.e., UniLaSalle 250, AGCO 1500, GIMA 1000, Groupe-ISA headquarter 700) in addition to 2000 UniLaSalle students, within an agglomeration of about 95,600 inhabitants.

FTI within a local agtech cluster (environment)

In a recent report, FAO pointed-out the risk that the application and dissemination of technologies could aggravate disparities (2017, p. 55), namely between high-income countries providing such technologies and recipient countries. Yet, disparities and farming technology divides can emerge also within western countries. For instance, a group of French farmers highlighted that acquisition costs are determining disparities in the FTI uptake because they can be met only by higher-income farming systems. On top of that, few adopters imply eventually their isolation and lack of nearby references to master these technologies that are, for the most, exogenous to agriculture (InPACT, 2016).

Agriculture is generally considered as a structural asset and as such its development is supported by dedicated policies and subventions. Indeed, the orientation of private investment in the sustainable development of agriculture depends on the policies and regulatory frameworks as well as on more general public investments in infrastructure and R&D (FAO, 2017, p. 129). Where the state cannot though directly change the strategies of FTI providers, such as in western countries, intermediary actors financed in part by public funds emerge to orient the FTI strategy. In this framework, the public sector seems more to play a catalytic role.

The environment appeared to be crucial in FTI for our case study. Regional strategic actions for FTI started in 2014, a year before the territorial reform that created the Haut-de-France by the merger between Picardie and Nord-Pas-de-Calais. In its Smart Specialisation Strategy (S3-2014-2020) the former Picardie region pinpointed societal pressure on sustainable agriculture, resulting in new needs for agricultural machinery and agronomic innovations. As such, the region decided to strengthen the regional dynamic around the agricultural machinery and precision agriculture on six axes (Région Picardie, 2014):

increasing the visibility of regional skills to encourage rapprochements between industries and R&D actors;

making the agricultural machinery industrial activities known to the regional mechanic industry, to involve convenience subcontracting;

supporting innovation;

supporting the establishment of supply chains for first transformation industrial sites;

accompanying companies abroad;

developing and adapting training schemes.

The Beauvaisis agglomeration provided continuity of this strategy within the new Hauts-de-France region by eliciting and supporting the creation of specialized intermediary organizations, targeted at playing a mediating role between the private industrial sector, higher education and farmers. It identified the UniLaSalle campus as a pivot in its territorial development strategy on the agtech sector because of the institute long commitment to education in FTI and its geographical and knowledge proximity to farmers. On the one hand, the Beuvaisis agglomeration branded the area near the campus as "technology park" dedicated to the establishment of actors of the innovation in the agfood sector. On the other hand, the agglomeration promoted the creation of intermediary actors and third places, thus convergenging with a more general trend for demand-driven agricultural research (Klerkx and Leeuwis, 2009). All this was institutionalized by the creation of a public-private cluster promoting the interactions of local FTI actors called Rev'Agro (Rizzo et al., under preparation)

Emergence of (open) labs and spaces to tackle FTI (management)

As for the first level of analysis, we want to observe here how innovation governance practices elicited the expression of relevant traits of local FTI actors. We specifically addressed the role of place dependent traits, *i.e.* the influence of the environment, as the main factor to evaluate the relevance of FTI strategic orientation management. In a context of structural mutations both for the agricultural machinery manufacturer, the regional cash crop farming systems and the agricultural higher education sector, the regional and local public authorities seem to have chosen to manage innovation through the creation of new places for private/public interactions. Of interest, private actors followed a private/private pathway for FTI. The common trait is the elicitation of interfaces with farmers, yet the relevance for actual farmers' empowerment it is still unclear. Accordingly, this paper focuses on the making of AgriLab®, a fablab and living lab dedicated to open innovation towards sustainable agriculture, spanning from equipment to digital tools. By comparing AgriLab® creation with concomitant initiatives, we set the scene to understand its role as a catalyst for the actual involvement of farmers in local and wider FTI.

(2015) Chair in Agricultural Machinery and New Technologies – Chair AMNT. Promoted by the Region Hauts-de-France, also with funding by and the EFDR European program, the Chair is hosted by UniLaSalle with the patronage of AGCO, Kuhn and the Michelin Corporate Foundation. It fosters the design and development of research, education and training in agricultural equipment and new technologies to support the transition towards sustainable agrosystems (Rizzo et al., 2018) by acting at the interface between students, industry sector and farmers and their organizations (e.g., CUMA, cooperatives, and technical institutes).

(2018) AgriLab®. Co-financed by the Beauvaisis agglomeration, the Oise Department and the Region Hauts-de-France, AgriLab is an open innovation platform officially registered in the fablab worldwide network. It is one of the few fablab explicitly oriented towards agriculture and farmers. It is inspired by FTI group of practice and makerspaces such as Open Ecology and Atelier Paysan. Its novelty is to be completely oriented and equipped to support innovation by and for farmers and other stakeholders of the agrifood sector (Dantan et al., 2019). One should bear in mind that fablabs are communities before of being places. As such, they are more frequently related to city-based communities that are limited in available space, especially when ran on own funds. Hence, the agfood themes are generally tackled as urban agriculture, aquaponics or food processing. AgriLab instead is specifically addressed to the farmers' community; as such it is placed outside the city and close to arable farmlands. This was allowed by public-private investments for the creation of the buildings, and benefits also from the involvement of private actors for the running and community management. A few months after its opening, local agencies of Credit Agricole, world's largest cooperative financial institution, and CER France, leading association and consultancy network in France, committed with AgriLab territorial anchorage and wider development.

(2018) Promize. The locus dependence of FTI is less constraining when dealing with digitalization. The GROUPE-ISA followed nevertheless a pathway similar to the others by creating a start-up, called Promize, that fosters a better interface with farmers, dealers, advisers and the like. This third place, claiming itself as autonomous, is meant to promote agility and adaptation to partners, to create added value for various agricultural stakeholders, especially about digital FTI, such as IoT, bigdata, artificial intelligence, robotic and blockchain.

(2019) Farmr. Farmers are and claim to be actors of FTI. On the one hand, there are structural mutations in the regional cash crop farming systems, and more in general in western agriculture, due to the continuous reduction in the number of farmers and the increase in the education level and technological mastery of new and upcoming farmers (Rizzo et al., under review). On the other hand, farmers are getting more isolated, both for the increase in farm size in western and northern Europe and for the diversification and complexification of available and emerging farming technologies (McFarland, 2018). Digitalization and social media could therefore palliate at the lack of neighbour peers when farmers need to tackle FTI (Phillips et al., 2018). Two young entrepreneurs, one of which issued from a family of farmers, launched a network entirely dedicated and limited to farmers, called Farmr. First of its kind, this network allows farmers to exchange knowledge based on their situated expertise. It represents the most advanced specialization of other platforms to facilitate the farmer-to-farmer connections, yet being the only one that excludes other private actors.

(2019) Pim@tech. The structural mutations in the agricultural manufacturing sector led to the creation of private-private interfaces. French manufacturers are making important investments in infrastructures with an anticyclic scope (Jouan and Paturel, 2019, p. 3). In our case study, AGCO both invested to extend the production facilities in Beauvais and to reinforce the R&D assets. In line with the creation of GIMA in 1994, the current strategy was to foster the interface with the Technical Centre for Mechanical Industry (CETIM). The latter is the French most important technical centre for mechanical industry, whose goal is to improve companies' competitiveness through mechanical engineering, transfer of innovations and advanced manufacturing solutions. Supported by GIMA and AGCO-Massey Fergusson, the CETIM is the general contractor for a new international centre of innovation in agricultural machinery, Pim@tech, also supported by Regional funds and located on the Beauvaisis technology park.

Conclusion and perspectives

This paper addressed the question: FTI are locus dependent? The answer depends on the definition of locus. Farming is a locus (place) dependent activity, as it was the manufacturing of agricultural equipment. The development of farming technologies implies an innovation system because it involves multiple actors carrying specific skills (cf. Lundvall, 2016), thus the interaction between multiple loci. Furthermore, the digital revolution that impacts several production sectors, is leading FTI to increasingly creating cyber-physic interfaces. The resulting mix of tangible and non-tangible dimensions ends up questioning the original locus-dependency of FTI. Based on a two-level analysis (i.e., European and local level), we adopted the gene x environment x management metaphor to observe how these changes are inducing the expression of latent traits in the involved actors. The hypothesis was that the emergence of third places such as fablabs, makerspaces and living labs are tentative answers to manage FTI in the interactions between the historical traits of actors and their evolving farming 4.0 environment.

France shows the highest number of fablabs in Europe. A possible reason is the French fablab model, which includes both officially labelled communities (i.e., adopting the chart and being part of the world network) as well as other projects issued from institutional support to local groups committed with similar principles (Bouquin et al., 2016, pp. 20–21). We focused on AgriLab as a unique case of a third-place aimed at bridging again, though in a new way, the earlier actors of the FTI with the farmers. At the wider level, a similar trend could be observed for FarmHack and Atelier Paysan. Nevertheless, the latter appear to be farmer centred, whereas AgriLab is community centred, yet with a focus on farmers. In this sense, AgriLab is both enhancing the connection of farmers with the local community and empowering farmers in the FTI. As such, it participates to the sustainable development program of UniLaSalle. On the reverse, AgriLab could represent a mutation of the UniLaSalle genotype: this higher education institute was founded for training the trainers and evolved so far to educate new generations of farmers and agronomists. However, the FTI is accelerating the pace of emergence of technical novelties, which are increasingly shaped by the digital transition. As such, the ten-years that usually pass between the degree and the taking over the farm are becoming too long. In a certain way, AgriLab allows filling the gap by opening the training directly to the farmers, while also changing the way of producing and transferring knowledge.

In conclusion, the community centred production and sharing of knowledge that characterises fablabs, makerspaces and living labs has been challenged by the creation of an open innovation platform explicitly oriented towards agriculture and the farmers community. On the one hand, this can produce a mutation in higher education by strengthening the links between farmers and the learning community. On the other hand, the needs of a higher educational institute can produce a further mutation in the fablab approach, to consider place-based knowledge to feed sustainable FTI. In perspective, more research has to be done about the role of AgriLab in the local and wider context of public-private-people partnership and to understand which historical, environmental and management conditions are required to reproduce it elsewhere.

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Author contribution. DR, AC, NS and FF conceptualized the study and framed the analysis of the literature. DR and FF selected the fablab related literature. DR and AC edited the manuscript revised by all the authors.

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Source Availability Statement: the public documentation about AgriLab® is on the dedicated collaborative platform and might be accessed from: http://agrilab.unilasalle.fr/

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SMART FARMING AND SHORT FOOD SUPPLY CHAINS: TWO DIAMETRICALLY OPPOSED ALTERNATIVES OR TWO SIDES OF THE SAME COIN?

Evagelos D. Lioutas [a], Chrysanthi Charatsari [b]

[a] TEI of Central Macedonia, Department of Supply Chain Management
[b] American Farm School of Thessaloniki

Abstract: Both smart farming and short food supply chain (SFSC) schemes are considered as promising alternatives to the conventional forms of producing and distributing agrifood products, having the potential to mitigate the environmental impacts of agriculture, to increase farmers' income and to produce new forms of value. Nevertheless, although smart farming has gained considerable momentum over the last few years, the integration of digital technologies and intelligent decision support systems in SFSCs has not yet been achieved. In this work, following a mixed research design, we aim at identifying farmers' and consumers' perceptions of and attitudes towards "smart SFSCs." Our results indicated that, although consumers who buy from SFSCs have a positive attitude towards smart technologies, they believe that their application in SFSCs will alter the unconventional character of short supply schemes. Such a "conventionalization" of SFSCs will lead to a change in farmer-consumer relationship, thus weakening the link connecting them. Farmers who participate in SFSCs express a mixed attitude towards smart farming since they perceive smart technologies as tools able to facilitate the achievement of higher efficiency but, on the other hand, they afraid that adoption of these technologies will create the need to restructure the modus operandi of farm enterprises. In both analyses, price and cost concerns were found to be important predictors of the general attitude towards smart SFSCs, but their contribution to predicting willingness to engage in smart SFSCs is limited. On the contrary, this (un)willingness is mainly driven by the symbolic content attributed to alternative food networks by both consumers and farmers. Qualitative findings confirmed that the major obstacle for the exploitation of smart technologies in SFSCs is their perceived incompatibility with the alternativeness of short supply schemes. For consumers, this incompatibility refers to the transgression of their imagery surrounding the concept of SFSCs, whereas for farmers it is associated with the need to redefine (once again) the meaning of farming. However, both samples were found to agree that the integration of smart technologies in SFSCs can increase the sustainability of short food supply schemes. Hence, smart technologies are viewed simultaneously as enablers of sustainability and as threats to the optimally distinct identity of SFSCs. In sum, these results reveal that smart SFSCs are conceived by both consumers and farmers as a Yin and Yang, combining seemingly opposite but potentially complementary paths towards sustainability.

HOW DIGITALISATION INTERACTS WITH ECOLOGISATION? PERSPECTIVES FROM ACTORS OF THE FRENCH AGRICULTURAL INNOVATION SYSTEM

Éléonore SCHNEBELIN [a], Pierre LABARTHE [b], Jean-Marc TOUZARD [c]

[a] UMR Innovation, DigitAg, Univ. Montpellier, INRAE, Institut Agro, Montpellier, France
[b] AGIR, Univ. Toulouse, INRAE, Castanet-Tolosan, France
[c] UMR Innovation, INRAE, University of Montpellier, 2 Place Viala, 34060, Montpellier, France

Abstract

Two major agricultural transformations are currently being promoted worldwide: digitalisation and ecologisation, that include different practices such as organic farming and sustainable intensification. In the literature and in societal debates, these two transformations are sometimes described as antagonistic and sometimes as convergent but are rarely studied together. Using an innovation system approach, this paper discusses how diverse ecologisation pathways grasp digitalisation in the French agricultural sector; and do not discriminate against organic farming. Based on interviews with key representatives of conventional agriculture, organic agriculture and organisations that promote or develop digital agriculture, we explore how these actors perceive and participate in digital development in agriculture. We show that although all the actors are interested and involved in digital development, behind this apparent convergence, organic and conventional actors perceive neither the same benefits nor the same risks and consequently do not implement the same innovation processes. We conclude that digitalisation has different meanings depending on the actors' paradigm, but that digital actors fail to perceive these differences. This difference in perception should be taken into account if digital development is to benefit all kinds of agriculture and not discriminate against organic farming and more widely, against agroecology.

Introduction

This paper deals with the relations between two major transformations of agriculture: ecologisation and digitalisation. Ecologisation is defined as "the growing importance of environmental issues within agricultural policies and practices" (Lamine, 2011; Lucas, 2021). Digitalisation refers to the increasing use of digital technology throughout the economy and society in general (Lange et al., 2020). Our aim was to understand how different ecologisation pathways grasp digitalisation. The originality of our approach is addressing the issue through the perception of digitalisation by French Agricultural Innovation System actors, that is, the set of diverse actors, networks, institutions and knowledge that enable innovation in the agricultural sector (Klerkx et al., 2012).

Ecologisation is promoted as a way to cope with the adverse effects of farming. These effects include loss of biodiversity, water, soil and air pollution, and climate change as well as food safety and occupational health issues. Schematically, two main ecologisation pathways coexist in agriculture, which their promotors each claim address these challenges (Dalgaard et al., 2003; HLPE/FAO, 2019; Plumecocq et al., 2018). The first corresponds to the sustainable intensification of the industrial model of agriculture. It consists in optimising inputs to increase efficiency and reduce negative externalities on the environment. The second promotes new practices that stimulate ecosystem services. It involves a more transformative and systemic reconfiguration of production systems mainly grouped under the general term 'agroecology' (Duru et al., 2015). Organic agriculture is usually recognised as belonging to the second ecologisation pathway, even if academic debate concerning their links or similarities continues (Abreu et al., 2012; Bellon and Penvern, 2014). Most research addresses the coexistence of ecologisation pathways through their ontological basis (Ollivier et al., 2018), their values (Plumecocq et al., 2018) and their actors' perceptions (Van Hulst et al., 2020). With the notable exception of institutional analyses of specific technological lock-in of certain crops or varieties, the role of agricultural innovation systems in the ecologisation of agriculture is much less widely studied (Magrini et al., 2016; Vanloqueren and Baret, 2008).

Alongside the promotion of the ecologisation of agriculture, digitalisation is also accelerating in the agricultural sector, with a bundle of new and diverse technologies (Van Es and Woodard, 2017; Wolfert et al., 2017). Digital technology consists of the codification of information through numbers which facilitates its transfer and storage. In agriculture, digitalisation covers a wide range of technologies including digital platforms or precision agriculture or connected objects or digital social networks. Here we focus on digitalisation at farm level. Through the hard-, soft- and orgware components of technology (Dobrov, 1979), digitalisation can transform not only farming tools, but also practices, knowledge processes, and work organisation. Digitalisation has led to the development of new products and services for farmers, to new knowledge and uses, but also to new players and networks in agricultural R&D (Fielke et al., 2020). On the other hand digitalisation can be framed by institutions, knowledge and actors from the digital sector as well as from the agricultural sector targeted here (Jakku et al., 2019), where it can lead to a specific digital agricultural innovation system (Fielke et al., 2019).

Although the relations between digitalisation and ecologisation are the subject of academic debate (Clapp and Ruder, 2020; Rotz et al., 2019; Wolf and Buttel, 1996), little work has directly addressed this issue. Some papers highlight the potential of digital technologies to support ecologisation of agriculture, to provide new knowledge, improve management of complexity and diversity, foster exchanges and innovations and reduce the agroecological workload (Bellon Maurel and Huyghe, 2017; Bonny, 2017). However, most social science papers are more critical of the compatibility between ecology and digital technology. Digitalisation could lead to simplification and homogenisation of production systems, loss of autonomy and of knowledge and instead promote a high-capital agriculture (Carolan, 2017; Plumecocq et al., 2018; Wolf and Buttel, 1996).

The development of digital technologies in agriculture is a process that involves a set of innovations with a strong systemic dimension (Klerkx et al., 2019). Digitalisation transforms not only exchanges of information and farmers' decisions, but also potentially the very knowledge and actors of agricultural innovation system (Fielke et al., 2019; Ingram and Maye, 2020). In other words, like other innovations, digitalisation is not neutral. It fosters system transformations and affects actors, knowledge, and power relations (Bronson, 2018). However, the systemic aspect of digitalisation and its directionality remains to be further explored.

The notion of Agricultural Innovation Systems (AIS) has been used at national scales to study the '*interactive development of technology, practices, markets and institutions*' in agriculture (Klerkx et al., 2012, p. 465), leading to a growing literature (Touzard et al., 2014). But AIS are not homogeneous. A "*plurality of socio-technical configurations, supported by different key actors pursuing different aims, and shaped by different rules, lock-in effects and path dependence, can potentially coexist in the current socioeconomic and political context*" (Dumont et al., 2020, p. 107). The diversity of agricultural models is embodied in a multiplicity of practices and is supported by a variety of institutions, organisations, and infrastructures. In other words, different paradigms built around ecologisation can coexist within AIS (Beus and Dunlap, 1990; Gaitán-Cremaschi et al., 2019). Paradigms are framed by actors and institutions, who structure power relationships (Sonnino and Marsden, 2006), thereby influencing the dynamics of agricultural systems and shaping their directionality (Pigford et al., 2018). Conversely, AIS can structure the coexistence of different forms of agriculture (Stassart and Jamar, 2009; Vanloqueren and Baret, 2009). The coexistence of paradigms may not only result in co-evolution and convergence, but also in differentiation, and divergence (Hervieu and Purseigle, 2015). As pointed out by Pigford et al. (2018), AIS tend to promote the dominant paradigm which frames technological trajectories and locks in other possible trajectories. Directionality of digitalisation is beginning to be included in the literature (Bronson, 2019; Carbonell, 2016; Klerkx and Rose, 2020). However, few studies include actors representing alternative paradigms, such as organic agriculture. Structural analysis of AIS makes it possible to account for the heterogeneity within the AIS and understand how it affects trajectory and directionality of the AIS.

The research question we address in this paper is the following: How do actors of the AIS in relation with different paradigms of ecologisation perceive and respond to digitalisation, and what are the points of convergence and divergence? We address the question by referring to the French agricultural context.

The paper is organised as follows. First, we present our analytical framework. We link the issues of digitalisation and ecologisation of agriculture through a structural analysis of sectoral system of innovation using Malerba's categories (2004). We propose an operationalisation of this framework that is consistent with the existing literature on the digitalisation of agriculture. We continue with a description of material and methods we used for our qualitative analysis. Our method is based on 38 semi-structured interviews covering the diversity of players of the French AIS. The results provide an overview of the perception and enactment of digitalisation according to the actors' paradigm. A perception of impacts and opportunities that is shared in some aspects across actors but with different aims and risk perception. We end with a discussion of our findings and their implications.

Revisiting the digitalisation process through an institutional analysis of the agricultural innovation system

2.1 Analytical framework: relations between digitalisation and the four dimensions of innovation systems

The sectoral innovation systems (SSI) concept was developed to analyse sectoral specificities in innovation (Malerba, 2004). In parallel, scholars have developed the concept of Agricultural Innovation Systems (AIS) specifically for the farming sector (see Hall, 2006; Klerkx et al., 2012). In the framework of AIS studies, innovation is considered as a '*complex web of related individuals and organisations – notably private industry and collective action organisations – all of whom contribute something to the application of new or existing information and knowledge'.* It *'includes the farmers as part of a complex network of heterogeneous actors engaged in innovation processes, along with the formal and informal institutions and policies environments that influence these processe*s' (Spielman and Birner, 2008, pp. 1, 2).

Actors' perceptions of innovation systems can be analysed from different perspectives (Klerkx et al., 2012), with the focus on processes (Nelson and Nelson, 2002), and interactions (Spielman et al., 2011), functions (Hekkert et al., 2007) or on structures (Knierim et al., 2015). We use Marlerba's analytical framework of the structures of sectoral systems of innovation (Malerba, 2002), which was already applied to digitalisation of agriculture by Busse et al. (2015). This structural analysis appears to be an appropriate way to grasp how the different paradigms connect to digitalisation within AIS. First, the framework is used to characterise change, i.e. the *transformation and evolution* of the variables of a sectoral system (Malerba, 2002, p. 258). Second, the framework is useful "*when the transformation of sectors involves not just traditionally defined sectors […], but the emergence of new clusters that span over several sectors*" (Malerba, 2002, p. 259). Third, Malerba himself acknowledged the importance of describing heterogeneity within the sectoral system of innovation (Malerba, 2002, p. 262).

The different ways of conceiving agriculture can be considered as different paradigms, i.e. different outlooks, along with the definition of relevant problems and of the specific knowledge required to solve them, supplemented by production, marketing and distribution conditions (Djellal, 1995; Dosi, 1982). The nature of the paradigm defines its boundaries, along with a framework for possible technological trajectories (Dosi, 1982) that are supported by specific institutions and organisations for knowledge exchange and innovation. Our aim is to point out how players involved in different agricultural paradigms, perceive and make sense of digitalisation, how they themselves grasp the digital concept, i.e. how they understand, are aware of, expect and transform digitalisation (Dufva and Dufva, 2018).

We analyse how actors engage with digitalisation using Malerba's categories: actors and networks, technologies, knowledge, institutions and public policies. Table 1 below provides an overview of our analytical framework, the categories and the actors we analyse and links them with the questions we aim to answer together with literature on digitalisation. Some of these studies show that the different actors of AIS (researchers, advisors, industry, farmers) have different expectations and perceptions of the risks involved in digitalisation (Fielke et al., 2019; Jakku et al., 2019). Depending on how they understand and enact digitalisation, the process of digitalisation can affect their identity and their organisation (Rijswijk et al., 2019). Moreover, the use of digital technologies can foster new learning processes and create new networks, new kinds of interactions (Eastwood et al., 2017, 2012). Digitalisation may exclude some actors, or reinforce the power of others, including upstream and downstream industries (Bronson and Knezevic, 2016; Ryan, 2019). Digitalisation can also encourage the entry of new players into a sector, in particular digital firms. Digital technologies are based on information. They influence information and knowledge processes (Higgins et al., 2017). Codification of information and knowledge makes them easy to diffuse and organise. But the codification process can change the nature of information, for instance by suppressing tacit knowledge or transforming it into explicit knowledge. In addition, organisations can benefit from knowledge creation and knowledge diffusion thanks to digital technologies. Interdependencies between humans and technologies influence workers' skills and capacities (Richardson and Bissell, 2019). Organisations can develop specific knowledge and skills to cope with digitalisation (Eastwood et al., 2019; Rijswijk et al., 2019). Digitalisation also affects both formal institutions (legislation, especially on data, public policies, etc.) and informal institutions (new ways to act, to communicate etc.), and reciprocally, institutions affect digitalisation. Institutions play an essential role in technology trajectories in agriculture (Hayami and Ruttan, 1971), and this role is underlined by many authors including Wolf and Buttel (1996), Wolfert et al. (2017), Eastwood et al. (2012), and Jakku et al. (2016).

Table 22

Analytical framework, inspired by Malerba (2002)

Category	Description	Questions	Literature informing the questions
Actors and Networks	Beliefs, assumptions, purpose	What do players expect from digitalisation? Which risks do they perceive?	Dufva and Dufva (2018) Jakku et al. (2016)
	Organisations, learning processes	How does digitalisation affect interactions within or between organisations?	Eastwood (2017) Rijswijk et al. (2019)
	Collaboration - Competition Interactions Communication - Exchange	Does digitalisation result in collaboration or in competition between organisations? Do digital players include/exclude certain AIS organisations?	Bronson and Knezevic (2016)
Technologies	Development of technologies	How do agricultural organisations engage in the development of technologies?	Jakku and Thorburn (2010) Rijswick (2019) Bronson (2019)
	Constraints and interdependencies of technologies	Are digital technologies on the market include the two paradigms? Do they account for their specificities? How are the technologies perceived? What curbs 'AgTech' development?	Carbonell (2016) Lioutas and Charatsari (2020)
Knowledge	Knowledge and skills within the organisation	How do organisations develop knowledge and skills for digital innovation?	Rijswijk et al. (2019) Eastwood et al. (2019) Jakku and Thorburn (2010)
	Learning process	Has digital innovation led to new sources of knowledge?	Ingram and Maye (2020) Eastwood et al. (2012)

Institutions and public policies	Laws Regulation Public policies Values Routines Practices	What roles do formal institutions play in digitalisation? How does digitalisation change formal institutions? How do institutions that are concerned with digitalisation articulate paradigms and digitalisation? How do informal habits, routines, practices, affect digital innovation in the paradigms and inversely?	Rijswijk et al. (2019) Wolf and Buttel (1996) Wolfert et al (2017) Eastwood et al. (2012) Jakku et al. (2016)

2.2 Organic and conventional as paradigms

To illustrate the diversity of paradigms within the French AIS, we focus on conventional and organic farming.

"Conventional farming" refers to mainstream agriculture, i.e. "*capital-intensive, large-scale, highly mechanised with monocultures of crops and extensive use of artificial fertilizers, herbicides and pesticides, with intensive animal husbandry*" (Knorr and Watkins, 1984 in Beus and Dunlap, 1990). This type of agriculture emerged in France in the post-World War II period in response to the political aim to achieve food security and has been supported by scientific, political and technical actors (Brechet and Schieb-Bienfait, 2006). In France, the development of conventional farming led to an increase in farm size (from 19 Ha in 1970 to 63 Ha in 2016), a reduction in the total number of farms (from 1 588 000 in 1970 to 436 000 in 2016), an increase in yield (e.g. for wheat from 4T/Ha to 7T/Ha) and of the use of inputs (+ 60% in volume) [102]. Conventional farming does not only involve the farm level, but the whole value chain including input suppliers, the food industry and retailers (Darnhofer et al., 2010). It has been supported by professional unions, advisory organisations, research and education. Hence, the construction of the AIS is inherent of the development of conventional agriculture (Labarthe, 2009). In France, conventional farming is mainly based on family farms, a component of the wider agro-industrial food system and has been studied as a paradigm by institutional economics (see Touzard and Labarthe, 2018 for a review). It supplies around 80% of French food (Fournier and Touzard, 2014). Criticized in France for its adverse effects on the environment and health, French conventional farming has changed over the last twenty years, notably through the integration of environmental concerns, supported by public policies (Duru et al., 2015). Some of the farmers linked to this paradigm have in fact opted for different forms of ecologisation, by optimising inputs or adopting more emblematic practices such as integrated pest management or no-till (Barbier and Goulet, 2013).

Organic farming emerged from social and ideological struggles against the development of productivist farming. The acknowledgment of organic farming within AIS, which was also framed by and for conventional agriculture (Brechet and Schieb-Bienfait, 2006), was one dimension of the confrontation between organic and conventional agriculture. The first organic group was created in 1959, followed by the creation of the French Association for Organic Agriculture in 1962. This movement led to the institutionalisation of organic farming with the creation of the Research Group on Organic Agriculture in 1978, official recognition of organic farming in 1980, followed by the creation of the organic farming technical institute (1982) and the organic label (1985) (Piriou, 2002). Thus, the development of organic farming is not only characterised by different practices and values at the level of individual farmers and consumers, but also by specific institutions and organisations which frame the balance of power in the AIS. Today, in France, organic farming is the most 'institutionalised' alternative paradigm. Its growth rate has been more than 15% for the last 15 years. Since 2018, organic farmers have been supplying more than 6% of French food and account for more than 8% of the agricultural area (Agence Bio, 2020)

Conventional and organic farming constitute two different paradigms, framed by specific actors, institutions, knowledge and organisation systems. Farmers who refer to one of the two paradigms co-exist in all the French regions, although organic agriculture has greater weight in the South of France (Gasselin et al., 2021). However, the limit between paradigms is sometimes blurred. At farm level, the ecologisation of conventional farmers can lead to practices that are very similar to those used in organic farming, and organic farmers can use external inputs similarly to conventional farmers. At the other stages of the food systems, economic organisations such as supermarkets may also choose strategies that combine organic and conventional products under general policy of food greening, which is sometimes confusing for consumers (Le Velly and Dufeu, 2016).

[102] The data come from the official census of the French Ministry of Agriculture available at: https://agreste.gouv.fr

2.3 Material and methods

Delimitation of innovation systems

The AIS framework underlines the importance of including a diversity of stakeholders who shape innovation in the farming sector (Hall et al., 2005). The AIS includes agricultural research and education organisations, advisory organisations, private sector actors in the value chain, agricultural cooperatives, public organisations, professional organisations and farmers (Klerkx et al., 2012; Spielman and Birner, 2008). We interviewed members of these different categories along with a number of digital players who characterise the dynamic frontier of this AIS (Fielke et al., 2019) (for a list of interviewees see ***Table 23***). We interviewed different categories of AIS stakeholders representing each of two paradigms (conventional and organic agriculture). The categories include farmers, value-chain players, advisory and political organisations, research and education systems, and public structures.

Digitalisation brings new actors dedicated to digital farming. Those actors may originate i) from digital firms which extend their activities to the farming sector, ii) from new organisations specialised in “AgTech” or iii) from existing organisations which create new activities (notably research and education) dedicated to digital farming. We interviewed actors who can play a key role in digitalisation directionality in agriculture, by selecting or prioritising one model, thereby strengthening or weakening organic or conventional agriculture

Another important aspect of an SSI is the technological profile of farm businesses, the demand of users of digital technologies, i.e. the farmers. We consequently conducted on-farm interviews which included the farmers’ use of digital technologies, their opinion on, and their role in the AIS. For this purpose, we selected both farmers with a representative role in organic or conventional agriculture, and farmers who play an active role in promoting or expanding/demonstrating digital innovation in agriculture.

Table 23

List of interviewees (n=38); Nat: National level; Reg: Regional level (Occitanie region)

Group		Organisation	Role
Transversal (n=5)	Tr-Minis	Ministry of Agriculture (Nat)	Digital manager
	Tr-PubAdm	Public administration (Nat)	Innovation manager
	Tr-PubRes	Public research institute (Nat)	Scientific programming manager
	T-Advis	Private advisory company (Nat)	Manager
	Tr-Journ	Journalist (Nat)	Author of a book on digital farming
Conventional (n=12)	Conv-ProfUn	Professional Union (Nat)	President
	Conv-AppRes	Private applied research institute (Nat)	Manager
	Conv-coopUn	Cooperative Union (Nat)	Innovation manager
	Conv-coop1	Cooperative company 1 (Reg)	Director
	Conv-coop2	Cooperative company 2 (Reg)	Innovation manager
	Conv-comp	Private company (Reg)	Innovation manager
	Conv-advis	Advisory Services (Nat)	Innovation manager
	Conv-coop3	Cooperative company 3 (Reg)	Technical manager
	Conv-farm1	Farm 1 (Reg)	Vice president of local professional union
	Conv-farm2	Farm 2 (Reg)	Vice president of local professional union
	Conv-farm3	Farm 3 (Reg)	Elected member of professional union and technical institute
	Conv-farm4	Farm 4 (Reg)	Member of a cooperative bureau, and president of an advisory company

Organic (n=10)	Org-advis1	Advisory Service (Nat)	Manager
	Org-advis2	Advisory Service 2 (Nat)	Innovation manager
	Org-ProfUn	Professional Union (Nat)	Deputy director
	Org-advis3	Collective organisation (advisory + applied research) (Nat)	Manager
	Org-ProfOrg	Professional organisation (Nat)	Director
	Org-PubRes	Public research institute (Nat)	Scientist
	Org-farm1	Farm 1 (Reg)	President of a professional union
	Org-farm2	Farm 2 (Reg)	Member of a national professional union bureau
	Org-farm3	Farm 3 (Reg)	Member of a collective organisation bureau
	Org-farm4	Farm 4 (Reg)	Elected member of a chamber of agriculture
Digital (n=11)	Dig-StUp	Start-Up (Nat)	CEO
	Dig-Res1	Research (Nat)	Project manager
	Dig-Res2	Research 2 (Nat)	Project manager
	Dig-Educ1	Education project (Nat)	Manager
	Dig-Educ2	Agro-digital observatory (Nat)	Manager
	Dig-firm1	AgTech firm 1 (Nat)	CEO
	Dig-firm2	AgTech firm 2 (Nat)	CEO
	Dig-assoc	Firms' association (Nat)	Director
	Dig-firmTIC	TIC firm (Nat)	Manager
	Dig-farm1	Farm 1 (Reg)	Sales and training agent in an AgTech firm
	Dig-farm2	Farm 2 (Reg)	Former sales and training agent in an AgTech firm

Sampling and interviews

We purposively selected interviews representing this diversity of actors (Etikan, 2016). Most interviews were conducted at national level, but in the case of farms and cooperatives, the interviews were conducted at regional level to ensure the homogeneity of the context. We chose the French administrative region Occitanie, which is characterised by the coexistence of organic and conventional farming. The farmers we interviewed were crop farmers because this sector has been the scene of digital and ecological development for many years. All the interviews were conducted in French, recorded, transcribed, translated into English by the authors and checked by a professional.

The semi-structured interviews were divided into four parts. The first part covered general information about the organisation, its history, its functions. The second part concerned the digital activities of the organisation. The third part addressed the interviewee's knowledge about farmers' use of digital technologies. The fourth part was more forward looking as we wished to collect information concerning the potential and the risks associated with digital technologies, and the links between digital technologies and agroecology. In the interviews, we mainly asked open questions to allow the interviewers to express their opinions freely without attempting to guide their responses too much. We had a list of Malerba's categories and if certain items on the list did not come up, we then asked the appropriate questions. This approach made the interview more flexible while ensuring nothing was forgotten. The interview was more natural, and the interviewees had more opportunity to talk spontaneously. In the interviews with the farmers, we first collected data concerning their farm and the rest of the interview was focused on their use of digital technologies, farming practices, micro-AKIS and their opinion on digitalisation.

Data analysis

All 38 interviews took place between March 2019 and March 2020. The interviews lasted between 50 minutes and two hours and were recorded and transcribed[103]. The transcriptions and documents provided by the interviewees were processed using MaxQDA© software. Data analysis was inspired by the methodology proposed by Ayache and Dumez (2011) and Miles and Huberman (1994). First, we read the transcriptions with no attempt at categorisation (Dumez, 2013). Next, we coded the transcriptions based on Malerba's broad categories as outlined above: actors and interactions, technologies, knowledge, and institutions. In each category, we created inductive sub-topics grouped in the eight sub-categories listed in Table 3. The first author coded all the interviews. Results of coding were discussed with the two co-authors, which led to a second coding process. Consistency was achieved by saturation. We condensed data using summary sheets of interviews and a matrix that cross-referenced themes of analysis and interviewees (Miles and Huberman, 1994). After listing the different results per actor and category in the first level of analysis, we added an inductive level of analysis to highlight the main transformations, gaps, and stakes involved.

Results

Our results show how the different categories of actors, i.e., those belonging to digital organisations and those who represent conventional and organic paradigms, perceive and enact digitalisation. ***Table 24*** summarizes the actors' statements concerning the different categories used for the data analysis. The following sections present the results according to the five major stakes that emerged: the diversity of expectations, the key role of knowledge and technologies, the new interactions between actors generated by this cross-sectoral transformation, the specific role of digital actors in the AIS, and the crucial issue of perceived risks.

[103] For technical reasons, interviews with two farmers were not been recorded and could thus not be transcribed

Table 24

Summary of actors' key perceptions and enactment of digitalisation

	Knowledge		**Technologies**		**Actors**		**Institutions**	
	Capabilities	Creation/Exchange	Development	Constraints	Global vision	Interactions	Formal	Informal
Organic	Developing farmers' skill is essential Lack of projects about digital and organic farming	Digital technologies enable sharing of experience, capitalisation of knowledge, ecological processes and the analysis of practices. Complementary to real exchanges	Internal development of technologies to capitalise on and exchange information/knowledge	Many of the technologies not suitable for technical, organisational, or economic issues	Possibility to manage complexity and the global technical, economic, social system Risk of dependence, of loss of know-how and power	Few partnerships with digital players due to differences in global vision of digitalisation; some informal exchanges	Environmental norms are associated with digitalisation There is no public support for digital technologies aimed at collaboration	Some actors' conception of farming may be against digitalisation because they can be based on costs/investment reduction, autonomy…
Conventional	Important development of digital skills within human resources of organisations to enact digitalisation	Need to develop data management to create value for their organisations – Added value is expected from the use of traceability data	Adoption of new technologies, co-development and development. Economic strategy: sell services, meet the demand for precise traceability	Problem of data ownership – of misuse by farmers – For farmers: need to better account for field realities	Digitalisation: a way to renew the economic model of farming organisations, change the negative image of farming, increase efficiency. Risks concern data ownership	Collaboration with digital organisations to test, to promote or co-develop digital tools. Could lead to market foreclosure	Legislation drives digitalisation - Need to adapt formal institutions to protect farmers' ownership of data and to ensure interoperability	Farmers' routines and culture are seen as a major obstacle to digitalisation

Specialised in Digital	Farmers' lack of skills curb the use of digital technologies. Digital organisations have the necessary skills to process data	Data and digital technologies could help experiment, model and predict, undertake global analysis…	Technologies are needed to help farmers digitalise their farms. Technologies are adapted to all kinds of farming including organic farming	Issues of data access, data quality, compatibility, complexity, economic models	Digitalisation is still in its infancy. Digitalisation is necessary for economic and environmental stakes. Data is an immaterial capital	Need for agricultural organisations to reach farmers. Digitalisation requires data sharing. Issues of governance	Legislation and regulation is at the basis of digitalisation but can curb some digitalisation	Farmers routines are a major obstacle to digitalisation
Transversal	Early investment in digital through regulation – Need for digital training for farmers	Data generated by digital tools could create knowledge but there is need for cooperation, sharing and means	No development of technologies	Potential of digital tools for environmental sustainability? Issues of adaptation to a diversity of farming systems	Digitalisation is seen as a potential for policy implementation – Digitalisation has potential but can have unintended negative effects	Digitalisation generates more interactions between agricultural players. Need to keep a watch on digital evolution	Legislation is a major development factor but innovation is not in their hands but in the hands of economic actors	Agricultural sector needs to change its habits to enable radical innovation

3.1. A diversity of expectations partly linked to organic vs conventional paradigms

The actors mentioned different expectations concerning digitalisation (cf. the *global vision* column in Table 3). Some impacts of digitalisation were expected by all. This includes optimising practices, accessing information and advice, gaining traceability, managing hazards and risks, or improving technical and economic management of the farms. Farmers also mentioned convenience and time saving. However, divergences can also be noted referring to communication with consumers, knowledge and value creation. Digitalisation is considered by conventional actors more as a way to create new economic opportunities while organic actors consider it more as a way to develop knowledge.

A set of opportunities identified by the interviewees concerned communication with consumers. Conventional actors mainly mentioned traceability as a way to improve communication and the marketing of agricultural products. One interviewee cited a statement heard at a meeting with a mass distribution actor: *"We're selling a product, it's true, but what we're missing is the story of the product.*" Using digital technologies, organisations can ensure increasingly precise traceability and hope to gain added value. Organic farmers see digital technologies more as a way to improve sales, to deepen interactions with consumers, or create direct marketing chains.

The development of environmental regulations and private standards (such as implementation of the HVE[104] certification in wine, or CRC[105] in cereals) promote digitalisation tools that are consistent with traceability.

"The regulatory obligation to register practices, manage organic fertilisation, register for the Common Agricultural Policy etc., are what actually drove farmers to digitalisation. » (Conv-advis)

Another set of opportunities concerned the emergence of a new market based on data and digital technology. Some conventional agricultural organisations consider engaging in digitalisation and being able to propose digital services to their farmers as an economic strategy. They invest in digital technologies to ensure they will still be present on the advisory market tomorrow and to find '*new economic models*' in the current legislative context (especially the obligation to separate sales and consultancy). For some of these organisations, the objective is clear: it is to sell services. Moreover, digital technologies are considered to be essential to cope with farming issues: environmental impacts, animal welfare, profitability, working conditions, attractiveness. Digital technology is seen as 'the future of agriculture' and as a precondition for their future survival. And also as a way to improve the image of the agricultural world in the eyes of society because it vehicles an image of a modern sector that embraces environmental issues.

"*So, we've got a market [plant protection products] that's probably going to decline. And so we have to position ourselves with respect to other niches that can be vectors of profit.*" *(Conv-comp)*

"It will help farmers show society […] that they are doing better and better and that they are willing to profit from all the new technologies to improve their production." *(Conv-ProfUn)*

In the same line of thought concerning digitalisation, agri-digital players underline the potential advantages of digital technology: gains in productivity, yield, time saving, security, forecasting, better management and communication, simplification, and efficiency. Data are seen as a value, as *"intangible capital" (Dig-firm2).* For these actors, digitalisation is seen as essential for the future of farming to cope with agricultural stakes including environmental problems, climate change and new societal expectations. They mention a necessary and inevitable transformation that will revolutionise farming. The use of digital tools in farming practices is seen as intrinsically

[104] HVE stands for 'High Environmental Value'. It is a public French certification launched in 2011 to label the global management of an environmentally friendly farm.("HVE," 2020)

[105] CRC stands for 'Controlled Reasoned Farming'. It is a French label which testifies to the sustainable cultivation of cereals ("*Filière CRC® - Culture Raisonnée Contrôlée*," 2020)

good and sustainable, as an objective *per se*. This development of digital technology "*is highly supported politically" (Dig-Res2)* and is strongly supported by funders and by research.

Members of organic organisations add expectations concerning learning and helping conceive the system, help in achieving systemic management of farms, creating links, exchanging knowledge, sharing experience and being able to make better observations.

3.2. Knowledge and technologies at the heart of digitalisation for conventional and organic organisations

Beyond these expectations and promises concerning digitalisation, interconnections between knowledge and technologies were underlined as major stakes by all actors. A need for knowledge is emerging with digitalisation, while digitalisation generates opportunities for the creation of new knowledge.

First, there was a consensus concerning the need for new knowledge and competencies to appropriate digitalisation. Conventional interviewees put more emphasis on knowledge at the organisational level, while organic interviewees put more emphasis on knowledge at the farm level (cf. the *capabilities* column in Table 3).

Conventional agricultural organisations emphasised the importance of developing new kinds of knowledge within their structure, such as agricultural cooperatives. Jobs and dedicated teams are being created specifically for digitalisation, and awareness raising and training are provided. Internal positions in agricultural organisations are even sometimes filled by digital specialists.

"farmers are more and more in need of experts (...). It forces us to train ourselves differently, or even to train people in certain aspects, etc." (Conv-coop2)

Organic organisations put more emphasis on the need to develop farmers' skills. The interviewees agreed on the need for new knowledge to increase organic farmers' autonomy to be able to appropriate the basic tools in order to manage they farm.

"*And mastering IT is essential for us[...] for people to be independent. We don't think it is complicated but [some say] it's too complicated for farmers and that it's not their job. We say it is possible to use the basic tools, and it creates critical thinking about their exploitation. » (Org-advis2)*

Developing skills at other levels, such as research and development, was also mentioned by organic actors, for instance by the French Scientific Committee of Organic Farming. However, these organisations have limited means and have other priorities.

Actors agreed on the fact that the development and use of a new technology create data opportunities that could help build new information and knowledge. The second column in Table 3 summarizes the interviewees' statements, showing that organic actors put the emphasis on knowledge creation concerning agronomic practices whereas conventional actors put the emphasis on the creation of information through traceability.

According to organic actors, digital technologies in organic farming would be useful to obtain information on regulations, trade, and machinery, to analyse and understand ecological processes, to help farmers conceive or think about their own system, to analyse their practices, while letting farmers take their own specificities and choices into account. Capitalising and sharing knowledge appears to be a key advantage of digitalisation, and these actors mentioned a '*conversion-support tool'* or a '*conception-support tools*' to help farmers engage in organic farming. They mainly considered that digitalisation could provide new "knowledge input" for designing, assessing, and sharing their farming practices. This will nevertheless still require physical and concrete approaches. The digital exchange of knowledge is seen as a way to complement real exchanges but not to replace them.

Conventional actors put more emphasis on the creation of information through traceability technologies to “better meet value chain standards and build consumer confidence and knowledge on the products”. Traceability is increasingly required by buyers (i.e. mass distributors, wholesalers, exporters) but is difficult to set up. Collective organisations hope to create knowledge as a result of data collection. However, they have difficulties in processing their data, due to a lack of resources.

Through digital technologies, digital companies hope to create new knowledge that will be a driving force for the development of their own business: digitalisation could create new forms of experimentation, new tools to perform global analyses of farming practices and environmental criteria, to improve modelling and forecasting.

“We are convinced that, as time goes by, a lot of know-how will come out of the vineyard. We are at the very beginning of the process because the speed of accumulation is not very high, so it takes time.” (Dig-firm1)

3.3. Different strategies regarding partnerships with digital actors

Cross-sectoral dynamic was perceived as a major factor for the development of the AIS. Digitalisation brings new actors and partnerships to the farming sector. Both start-ups and firms from other sectors invest in agriculture, leading to new kinds of interactions between actors (cf. the *interactions* column in Table 3).

One might think this would limit the role of agricultural organisations, but this is not the case. Agricultural organisations, i.e. cooperatives, associations, chambers of agriculture, commercial firms and advisory providers play a central role, especially in data collection but also in data "redistribution" and in the diffusion of technologies. Many digital players say that they cannot access farmers directly. They need farmers-based intermediaries to collect the large amount and diversity of data needed to run data-based tools. Agricultural organisations are also needed to legitimise digital projects.

“The objective [for our company] is not to sell directly to farmers but to sell to cooperatives or traders or management centres – which will be distributors of our solutions to farmers, because they have a self-interest in collecting and federating data to carry out their work […]” (Dig-firm2)

However, we noted differences between paradigms. Digitalisation is seen by conventional actors as an exogenous change and by organic actors as a more endogenous one.

Conventional organisations work in partnership with digital actors at different levels: to test, co-develop, or promote digital tools. These interactions may be informal or formal. When agricultural organisations collaborate with a digital firm, they position themselves as distributors, but also as service providers. They also offer support and training to farmers. In other words, they wish to transform the technology into a service they can sell to farmers. Conventional organisations see digital partnership as strategic. Digital technology is said to be increasingly providing inputs combined with advice, with machinery, with knowledge, via data links. According to one interviewee, that could lead to market foreclosure and reinforces their opinion that digitalisation is an important business strategy for them.

Organic actors are less involved in collaborative projects with new digital actors. On one hand, digital actors do not often call upon and work with the actors of organisations specific to organic farming.

« But by working with everyone in a balanced way, we mostly work especially with those who are most prominent. And you don't work much with small producers, agro-ecology". (Dig-Res1)

On the other hand, when organic organisations are called upon, it does not necessarily work out well because of the differences in the way they work and differences in values. Additionally, organic organisations have other priorities and do not have the financial means to invest more in digitalisation.

"Each time, the choice, the cultural difference is a little too strong. Even if we have a similar attitude to environmental issues, our methods are quite different." (Org-advis3)

Although organic digitalisation is thus considered in a more endogenous way, organisations do have informal exchanges with digital players and follow the development of digital technologies.

Developers of digital technologies consider developing partnerships between organisations to be strategic. They claim that digitalisation will require organisations to set up an ecosystem to develop information systems. Sharing data and ensuring compatibility is essential to achieve efficient digitalisation. Beyond the strategic partnerships, some digital actors regret the limited space accorded to farmers in digital projects.

3.4. Digital actors do not perceive heterogeneity within AIS

Digital actors bring a new perspective to the AIS. They underlined governance issues between the different categories of actors but did not perceive differences between organic and conventional farming.

Digital actors aim to support farming through the process of digitalisation. Digitalisation is seen as an objective per se for the agricultural sector, which will have to digitalise to increase its economic and environmental performances. In the opinion of digital actors, farmers are not aware of the advantage of digitalisation and are not particularly attracted by the idea of using digital technologies. The digital organisations we interviewed either develop technologies directly (start-ups, firms), are involved in projects to develop technologies (research, TIC firm) or test technologies (educational organisations). The TIC firms want to transfer their technologies from other sectors to the agricultural sector.

"We need to evangelize, to make people understand the ins and outs of what we do" (Dig-StUp)

Digital organisations consider digital technologies suitable for both organic and conventional agriculture. They do not consider 'organic' as a differentiation criterion.

"In fact, at least since the beginning of the project, I don't have the impression that being organic or not influences the interest we have in it or not. I have the impression that it is transversal." (Dig-Educ1)

Digital organisations see diverse impediments to their development in the agricultural sector. First, concerning access to data, they mention several obstacles including data quality, compatibility and technological interoperability, the cost of the technologies and the constraints caused by the specific farming context, especially long-term temporality, variability and complexity. Second, concerning data management, they underline issues of governance. Third, concerning the acceptability of their technologies, they are aware that digital technologies lead to outsourcing part of the analysis, which may discourage farmers from adopting the technologies. Fourth, they emphasize the capacity of the farmers to pay and to use digital technology.

"To do big data and analysis, you need good quality data. And that's hard to get" (Dig-assoc)

"And in all projects, whatever the technology, the weak link is governance." (Dig-Assoc)

"When we use an interface like ours there is this idea that behind it they [farmers] outsource part of the data analysis and they have to accept that. And I think that's very difficult to accept." (Dig-firm1)

3.5. The crucial issue of perceived risks by actors from the two paradigms

The actors emphasized the risks associated with the opportunities they mentioned. Organic actors underlined risks related to knowledge while conventional actors underlined the value of the data.

Both organic organisations and farmers listed many risks: in particular, that these technologies are too expensive, the risk of becoming dependent on them and of losing power, the "risk of standardization", the risk of data-hacking or data appropriation. Other risks mentioned included stress or the time required, loss of concrete interactions between people, loss of connection to the land and loss of local knowledge. Specific problems were mentioned when farmers do not have the necessary digital tools or the necessary skills to use them. Digitalisation sometimes -and in some ways- does not match the philosophy of some organic farmers or is simply too disconnected from their way of life. In particular, organic farming may reduce costs and investments whereas digital technologies may require investments.

Consistently, not all the digital technologies currently under development are considered to be suitable for organic farming, either for technical or socio-economic reasons: they may not suit the economic model, the farmers' ways of thinking and decision making, etc. As one farmer pointed out, he cannot use his farming software properly because it is not designed for a global reflection about the farm: it is designed for a technical itinerary, or plot management rather than for general management at scale of the whole farm. The farmer's reservations are reflected in a comment made by an advisor:

"But for us, in the way we advise, we consider that in organic farming, decisions must really take the whole farm into account (…). You either have to visit the farm or at least talk on the phone, and give really customized advice. » (Org-advis1)

Digital technologies are complex and complete control over them does not seem possible to those actors. This could change the balance of power between actors.

"Beyond loss of know-how, the balance of power in an agricultural system will be upset. In other words, we're going to be very dependent on the equipment or services provided in connection with these devices, on data processing, which is sometimes a little bit of a black box too." (Org-advis3)

To ensure the technologies meet the organic organisations' own requirements, they may develop them in-house, often through a bottom-up innovation process: an innovation is designed, implemented and tested on a local scale and then, if it works, it is upscaled. Most of the technologies developed by organic organisations concern knowledge management and exchange.

"So we obtained the tool at the national level, we invested some money in using and improving it based on the feedback we had already received, and that was good because we had a very good basis." (Org-ProfUn)

Conventional actors underlined the risks associated with data ownership, especially the risk that AgTech actors grab all the value created. They also mentioned the risk of farmers being excluded, because of the lack of infrastructure, skills or because of the cost. Farmers mentioned additional risks concerning the reliability of digital technologies and dependence on repairing it, and stressed the risk associated with the extra cost of the equipment when farmers already face economic problems.

Uncertainty concerning the value of the data, farmers' capacity to understand the potential of the technologies, and misuse of tools by farmers are cited as constraints by organisations involved in the development of digital technology. For their part, farmers testified to the need to better account for on-field realities in the design of digital technologies.

It is thus clear that diverse visions of digitalisation co-exist. Depending on the vision of digitalisation they vehicle, institutions that frame digitalisation could thus promote the directionality of this trajectory.

Discussion

In this paper, we address the question of how actors of AIS perceive and respond to digitalisation depending on their relation with the two different ecologisation paradigms. We highlight convergences and divergences.

4.1. Digitalisation beyond paradigms

Our research confirms that digitalisation not only changes technological possibilities but is involved in the reorganisation of the whole AIS in interrelationship with multiple factors, as suggested by previous studies (Busse et al., 2015; Fielke et al., 2019; Rijswijk et al., 2019). Interactions among actors, knowledge and institutions are jointly modified by digitalisation within the AIS, revealing characteristics that are shared across different ecologisation paradigms.

i) Whatever their paradigm, agricultural organisations play an important role in digitalisation, by acting as an intermediary between digital firms and farmers, but also by being proactive actors of digital development and in gathering, analysing and transferring information. Digitalisation does not reduce the role of intermediaries, but may even reinforce it, as shown by Busse et al. (2015). This is a further illustration of the role of innovation brokers in agriculture (Klerkx and Leeuwis, 2009).

ii) All the actors we interviewed agreed on the potential of digitalisation to improve working conditions, to optimise practices and to manage risks. They also mentioned possible advantages for economic management of farms, traceability, information for consumers, information and training for farmers. Digitalisation of agriculture is thus a part of the regime of “technoscientific promises” (Joly, 2010).

iii) On the other hand, all the interviewees mentioned different risks that could limit the adoption of digital technology or lead to the exclusion of farmers. Economic risks for farmers are described as being linked to the cost of the technologies, lack of skills or dependence on outsiders to repair the machinery. With the exception of ‘digital farmers’, farmers agreed on other risks concerning data hacking or data appropriation by value-chain actors. They also referred to the risk of the technologies not being appropriate for small farms. These results are consistent with the perception of digitalisation in the New Zealand AKIS, and of Big Data in the grain industry in Australia (Jakku et al., 2016; Rijswijk et al., 2019).

iv) The need to take control of the ongoing digitalisation was mentioned in both paradigms. Actors of the AIS want to be pro-active agents of digitalisation rather than passive receiver. They aim to reach the final stage of digi-grasping described by Fielke et al. (2021). All those interviewed emphasised that digital technology should complement other kinds of innovation, not only technological innovation. This is recognized by Rotz (2019) as a major challenge to digitalisation.

v) Digitalisation affects knowledge in a back-and-forth movement: it creates a need for new knowledge for digital technology, while simultaneously creating new knowledge. The creation and diffusion of knowledge is a major evolution, as shown by the literature review by Fielke et al. (2020). But making this knowledge effective turns out to be complicated, because of the diversity of needs and the context, and the management of complexity, among others. Several organisations claim they have data but cannot perform the analysis because they do not have the necessary means. Various transversal actors even think the value of the data is a myth: they believe agricultural actors hope to exploit the value of data, which will not happen.

vi) Regulations, standards, and specifications were considered by the interviewees as major drivers of the accelerated development of digital technologies. Digital technology may be both the cause and the consequence of changing regulations, allowing new kinds of regulations to be established and enabling new forms of control and traceability (Pearson et al., 2019).

On all those points, digitalisation appears to be more a source of convergence than of divergence between actors with respect to the conventional versus the organic paradigm. This convergence results from the perception of shared advantages (better information, work made easier, etc.) or problems (autonomy, learning and evaluating the technologies, etc.). Our results provide a basis for reflection or action on digitalisation that incorporates the diversity of farming systems.

Convergence may also be linked to the changing dichotomy between paradigms, as this distinction has become less clear (Sonnino and Marsden, 2006). The rapid development of organic farming is leading to hybridisation mechanisms between organic and conventional organisations. On the one hand 'conventional' organisations, especially cooperatives, are extending their activities to organic farming (Stassart and Jamar, 2009). On the other hand, organic farming organisations are incorporating innovations that allow them to scale up and "become conventional" (Le Velly and Dufeu, 2016). The distinction between the two paradigms and their institutions is still applicable. However, in practice, there is more and more a form of continuum. Thus, some "conventionalised" organic actors may have a "conventional" vision of digitalisation.

4.2. A diversity of desired trajectories of digitalisation

Although this digital transformation is global, it is not perceived in the same way by all the actors and points of divergence exist between organic and conventional players concerning their 'digi-grasping' (Dufva and Dufva, 2018; Fielke et al., 2021). Digitalisation could reinforce different directionalities of the AIS.

i) The main differences between organic and conventional players appears to be in the directionality each expects of digitalisation.

Digitalisation for traceability is expected by conventional actors whereas organic actors mention the risk of standardisation, fearing that the "industrialisation" of organic products may result from norms linked to or imposed by digital technologies aimed at promoting traceability (Klerkx et al., 2019; Ringsberg, 2014; Rotz et al., 2019).

Digitalisation for endogenous knowledge is expected by organic actors, who hope digital technologies will help them conceive and analyse their production systems in a systemic way and will support experimentation. However, this is not how digital technologies are currently designed, they are more segmented than holistic, more top down than bottom up. This could lead to discrepancies between digital technologies and organic farming. Organic actors mention the potential risks of loss of power and know-how.

Digitalisation for value creation is expected by both conventional and digital actors, who hope to improve the image of agriculture and its attractiveness, to improve profitability,

and limit environmental impacts. Conventional farmers and their organisations mention risks concerning the ownership of data.

ii) Here we refer to different innovation processes and strategies of digitalisation. Organic players underline the importance of farmers' training and of the design specific technologies to support their own vision of digitalisation. Conventional players collaborate with digital players with the aim of rendering farmers' activities simpler and more efficient. Thus, players involved in digitalisation differ because organic organisations focus on internal development while conventional organisations develop technical and economical partnerships.

iii) However, in our interviews, the digital actors did not perceive these different views. They work with the most influential actors and see no difference between organic and conventional farming. They consider that most digital technologies are generic and consequently appropriate for both conventional and organic farmers. However, the knowledge basis differs between organic and conventional farming, and, to be successful, farmers' knowledge must be included in digital technologies (Rose et al., 2018). Including actors in the conception of the tools is essential if the end users are to make sense of them (Bronson, 2019; Jakku and Thorburn, 2010). Not considering the diversity within the AIS, and consequently not incorporating this diversity in the conception of tools could lead to the exclusion of other forms of farming than conventional. It could reinforce the dominant paradigm. Conversely, a diversity of digitalisation could reinforce their differences.

Here, we consider organic farming as one example of the paradigm that embraces the agroecological transition in France, but not as the only one. Moreover, the diverse conception of digitalisation depends on a diversity of factors, not only on paradigms. It opens research opportunities to study digitalisation for new forms of alternative farming, or in other places, or depending on other factors.

4.3. Enriching the analysis of digitalisation of AIS by taking heterogeneity and power relations into account

Structural analysis based on Malerba's framework highlighted transformation of the AIS for and by digitalisation, while accounting for change in the nature of the AIS variables, cross-sectoral dynamics, and heterogeneity within the AIS. This analysis enabled us to highlight both convergence and divergence within the innovation system concerning the process of digitalisation in agriculture. Our conclusions are in line with the results of Fielke (2019), who showed that digitalisation leads to power issues and pointed out that powerful incumbents may capture more gains through digitalisation. There may thus be power issues between the different stakeholders (AgTech actors vs farmers for instance). We add possible power issues between different types of farming systems and different visions of digitalisation. Research by Bronson (2019; 2016) supports the fact that digital technologies are meaningful for conventional farming. Our research is complementary, as it provides insights into how digitalisation could be meaningful for organic farming according to the interviewees. It seems there is no opposition against digitalisation per se, rather against a certain definition of digitalisation that currently predominates. This conception of digitalisation tends to be prescriptive, requires high investment, concentrates power and standardises production. It is supported not only by private actors but also by some public actors (Lajoie-O'Malley et al., 2020)

This situation calls for the inclusion of the paradigm concept and of power relations in the innovation system. It invites scholars to analyse not only how digitalisation happens but also its possible directionality and how it is steered by the AIS. Transversal actors could work with digital actors to make the latter aware of this issue and to promote a diversity of research and development to avoid lock-in in digitalisation. This raises the question of the governance of digitalisation. Governance will influence which opportunities digitalisation responds to, which risks it will avoid, and consequently, which farming paradigm it will encourage. In line with the conclusion of Newton et al. (2020), it is essential to involve farmers and citizens in the decisions concerning the trajectory of digitalisation. We add the need to involve a diversity of farming systems in order to promote their diversity. In that respect, functional and relational analysis could complete this work in identifying blocking mechanisms and incentives (Bergek et al., 2008). Directionality of change also depends on the use of digitalisation by producers and the constraints they face, which, in turn, calls for further research on farmers' concrete uses and practices of digital technology.

Conclusion

Our result prompt us to take a step back when referring to the concept of digitalisation. In practice, digitalisation is not a single phenomenon with a single definition: it does not mean the same thing to different actors. Digitalisation may have different objectives, occur in different ways, and in different forms. We argue that there are no different 'stages' of digitalisation. All actors are engaged in understanding, awareness and transformation of digitalisation. But we suggest that there are different 'processes' of digitalisation. However, we question whether the coexistence of different processes of digitalisation is possible or whether power imbalances will impose a standardised digitalisation, meaning only the future imagined now by dominant actors will become reality (Carolan, 2020). Our findings thus call for the inclusion of heterogeneity in AIS to enable the development of technologies that suit different trajectories of ecologisation. We provide conceptual and empirical elements to help actors become aware of this heterogeneity. Moreover, many interviewees emphasised that digital technologies are but one component of transformation, others being changes in advisory services, in farm structure, new relations with consumers, new policies supporting open innovation. Thus, the popularity of digitalisation should not mask other dimensions of AIS and there is a need to explore further their interrelations.

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