Social and Technological Transformation of Farming Systems:

Diverging and Converging Pathways

Proceedings of the 12th European IFSA Symposium
12th - 15th July 2016 at Harper Adams University, United Kingdom

Volume 3

Andrew Wilcox and Karen Mills (Eds.)

Harper Adams University

IFSA
INTERNATIONAL FARMING SYSTEMS ASSOCIATION
EUROPE GROUP

The Horizon 2020 CAPSELLA project: Collective Awareness PlatformS for Environmentally-sound Land management based on data technoLogies and Agrobiodiversity

Lazzaro, M.[1], Bàrberi, P.[1], Calabrò, G.[2], Toli, E.[3] and Ioannidis, Y.[3]

[1]*Institute of Life Sciences, Scuola Superiore Sant'Anna, Italy*

[2]*Zephyr s.r.l., Pisa, Italy*

[3]*Athena RC, Maroussi, Greece*

Abstract : Only agricultural and food systems with reduced use of external inputs can meet the challenges of sustainability. Agrobiodiversity is key to this, being the basis for improving agricultural production through smart utilisation of the functionalities that agroecosystems offer. Improving food systems where consumers play an active role in driving produce demand and offer is also crucial. Alternative, agrobiodiversity based agricultural models are more likely to be supported by open, horizontal and dynamic Agricultural Knowledge and Innovation Systems in which research, education, extension, support systems and farmers, citizens and consumers, are gathered in networks. Just like the tiny yet sturdy little plant it takes the name from, the Horizon 2020 CAPSELLA project (www.capsella.eu) will deepen the roots of sustainability in agri-food systems by harnessing scientific and local knowledge, people's energy, motivation and innovation skills around the theme of agrobiodiversity by making use of novel, improved and demand-driven ICT solutions. CAPSELLA will focus on two complementary domains (agrobiodiversity and the food supply chain) through participatory bottom-up data collection and top-down data integration to develop solutions. The project will build from scratch open data repositories concerning regional agrobiodiversity, and build upon and enhance existing data sets on the agrobiodiversity and food domains. Based on these, the project will develop a number of community-driven data powered ICT solutions, which will be tested by the communities engaged in the project and will result in a number of pilots running around three multidisciplinary, community-driven use cases: the field, seeds and food scenarios.

Keywords: ICT solution, innovation, participatory approach, functional agrobiodiversity, food supply chain, Agricultural Knowledge and Innovation System

CAPSELLA and the EU institutional framework

With over 77% of the European territory classified as rural (47% farmland and 30% forest) and around 12 million full-time farmers, agriculture is a vibrant and important sector of the EU economy and welfare. Agriculture and agri-food account for 6% of the EU's GDP, comprising 15 million businesses and 46 million jobs.

In this light, the European Union has always put a high priority on its rural development policies, considered key drivers of social and economic development and wealth. The main tool by which Member States implement their policies for agricultural development is the well known Rural Development Plan (RDP), one of the two pillars of the Common Agricultural

Policy (CAP). Through the CAP, Europe is increasingly recognising the value of farming for the conservation of agricultural biodiversity and the provision of ecological services in farmland, including some of paramount global importance, like the mitigation of climate change.

EU farmers are facing multiple challenges to meet increasing demands from consumers and the civil society. Besides their traditional role of food, feed and fibre producers, farmers are nowadays requested to provide other ecosystem services, such as the production of renewable energy, the conservation of biodiversity and the environment, landscape and rural cultural heritage, and the mitigation of climate change. Basically, there is an undeniable increasing awareness that all these demands can be met by the conservation and wise use of agricultural biodiversity or 'agrobiodiversity'.

To meet the present goals of EU agricultural and agri-food systems and to foster knowledge on the importance of agrobiodiversity among EU stakeholders and actors, the use of novel ICT solutions is key. Targeted and tailor-made ICT-based solutions can promote innovative, knowledge-intensive farming systems and methods based on the optimisation of local natural resources and on reduced use of external inputs. On top of this, ICT can greatly contribute to bridging the digital divide between urban and rural areas, thus creating a more inclusive society for the benefit of all actors involved.

In the light of the aforementioned concepts, under the Horizon 2020 programme, the CAPSELLA (Collective Awareness PlatformS for Environmentally-sound Land management based on data technoLogies and Agrobiodiversity) project was funded and took its first steps on 1 January 2016.

CAPSELLA's ambitious goals are: to raise awareness about existing ICT solutions and the benefits of their adoption; improve the understanding and collection of farmers' and networks' needs and requirements in order to develop and deliver tailor made ICT novel solutions; and to foster understanding and, hopefully, sharing of open data among farmers. This will lead to the building of a sustainable technical prototyping platform, a meeting environment for innovation that democratises access to big data, cloud computing, open data, open software and pilots.

How CAPSELLA will support and facilitate transition to agrobiodiversity

CAPSELLA is grounded on the scientific vision that diversification (whether in agriculture, land management, food retail or business models), supported by smart, open and distributed ICT tools, can have a significant impact on environmental and socio-economic sustainability. There are two ways by which this can occur. First, ICT can be used as a communication platform for information, experience and best practice sharing[1]. For example, agricultural biodiversity can make substantial use of novel ICT solutions that harness the power ICTs are offering, while keeping a clear local and bottom-up approach that serves the needs of networks, communities and small producers. The creation of open, bottom-up ICT tools, which are tailor made to the farmers' and communities' needs and requirements that will be collected, and dedicated to biodiversity for food and agriculture, would result in collaborative virtual work spaces in which innovative, diversity-based strategies of resources management, production,

---

[1]This is already happening with the widespread use of Twitter, especially in Anglophone farming communities (http://www.farmingfutures.org.uk/resources/how-use-twitter and http://www.theguardian.com/environment/blog/2014/jan/12/felfie-farmers-social-media).

distribution and consumption can overcome their current case-by-case success status and concretely contribute to the construction of a sustainable decentralised agricultural model.

This leads to the second way ICT can be used, i.e. directly, by using data to better manage the various steps along the food system. This includes, for example: the reduction of external inputs to industrial agriculture using the approaches of Precision Agriculture/Farming; the use of various data driven technologies based on local sensors, remote sensors, meteorological data, water consumption and reduction etc., to better manage crops; the use of local social networks to reduce food waste; and the use of smartphone apps to track and better inform consumers about the history or background of individual foods, etc. This can be seen as a continuum of various applications of ICT ranging from those purely industrially focused to those most socially/environmentally focused.

Methodology

CAPSELLA will focus on two complementary domains: agrobiodiversity and the food supply chain, in order to address the challenges of sustainability. The driving force of the project is its **bottom-up approach**, which aims at ensuring that the needs and requirements of involved communities, networks and clusters such as ESAPODA in Italy, Aegilops and Ars Natura in Greece, Arc2020 in the UK and others, are suitably and effectively addressed. Communities will first lead the decisions on what type of tools and pilots are going to be developed and will then evaluate and validate them.

At the centre of the work are three community-driven use cases/scenarios that will be addressed following an iterative approach:

1. **Field scenario**, addressing ecological intensification and functional agrobiodiversity in cropping systems;
2. **Seeds scenario**, addressing on-farm genetic diversity conservation and management, seed networks and informal seed systems;
3. **Food scenario**, addressing the food chain by bringing more transparency into the processes related to the production, distribution and consumption of quality food.

These use cases are transdisciplinary and will result in a number of bottom-up generated pilots with concrete value for the networks and communities involved. All these activities will be supported and linked together by a data integration and analytics platform that will enable a series of key functionalities for the user communities. These will include among others: (a) data capture via smartphones (e.g. recording of crop choices, growing patterns, and other relevant biodiversity data points); (b) unstructured data/update sharing with selected community members; and (c) wiki-like facilities to provide space for construction of narratives about food varieties (biodiversity) or food qualities. A further set of functionalities will be developed in collaboration with our target users as a response to their custom needs. The platform will integrate seamlessly with web-based and smartphone based delivery formats.

Finally, because CAPSELLA has a strong focus on innovation and the creation of concrete results, and hence societal impact, several activities able to turn ideas into applications and businesses have already been implemented. The requirements collection and solution development will rely on innovative tools such as ‘hackathons’ able to generate, in a collective way, bottom-up solutions. In the last 12 months of the project CAPSELLA will incorporate an even stronger “lab to market” approach, offering concrete incubation support and opportunities to ICT solutions developed within the project (Figure 1).

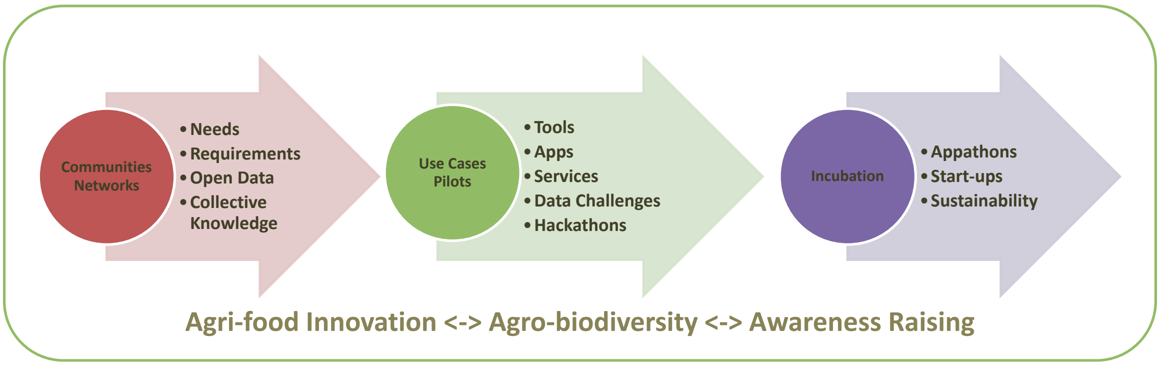

Figure 1. Flow chart of CAPSELLA’s activities.

CAPSELLA’s ambition

CAPSELLA advocates and strongly believes and supports the idea that a focus on **diversification**, either in agriculture, land management, food retail or business models, supported by smart ICT tools, will have a significant impact on sustainability. Agricultural biodiversity requires novel ICT solutions that harness the power that data driven solutions are offering, while keeping a clear local and bottom-up approach that serves the needs of networks, communities and small producers. The ambition of CAPSELLA is to establish agrobiodiversity as the key element to foster long-term sustainability in the EU agriculture and food sectors (and the EU environment) through long-lasting collaboration between farmers, farmers’ organisations, agricultural extension services, citizens, scientists, entrepreneurs, public servants and policy makers - generated from bottom-up participatory action boosted by targeted, on-demand novel ICT tools and solutions.

ICT tools have played an active role in agriculture since the 1960s and have been applied within the food and agricultural industries for improving efficiency and productivity in established food systems. It has been recognised that ICT holds the key to the successful coordination and implementation of a more sustainable agri-food system (Schiefer, 2004). The use of ICT could result in secure sustainable food systems, through the application of innovative digital technologies that take into account the interactions within and between food and agriculture systems, and with broader industrial systems. ICT could play a pivotal role in improving communication between different parts of the supply chain[2], as well as through the use of data driven technologies and other innovative digital technologies to improve the efficiencies of the overall food system – from sustainable production through to reduction of waste in supply chains and on the consumer’s table (Kaloxylos, 2013). Since agriculture and food chains are complex decision spaces, multidisciplinary research and user orientation are essential for a successful progress in ICT (Kuhlmann & Brodersen, 2001).

Agricultural production is required to increase while reducing its impact on the environment. This challenge is most effectively addressed through ‘ecological intensification’ (e.g. Tittonell, 2014), according to which agricultural production is based on an optimised management of agrobiodiversity and ecological processes, therefore creating a highly knowledge-intensive production system (Doré et al., 2011). Equally importantly, we need to ensure a fairer

[2] *cf. http://www.smartagrifood.eu*

distribution of food, which calls for investments in family farming, value chains and markets that enhance food security at all levels. The high level of complexity and unpredictability of the context of agricultural production and food chains (Gianpietro, 2003) brings us to the centrality of the concepts of 'adaptive management' and 'co-management', i.e. *"a continuous problem-solving process, rather than a fixed state, involving extensive deliberation, negotiation and joint learning within problem-solving networks"* (Armitage et al., 2009; Carlsson & Berkes, 2005).

Open data are key to the achievement of these goals. There is an enormous amount of knowledge available from a lot of different sources: the practices of indigenous communities; new technologies developed by research institutions; tacit knowledge; knowledge transferred between generations; policy implementation; and the use of products by consumers. Access to these data can help us understand all aspects of food production (soil conditions, land use, the dynamics of the value chain) and to identify gaps in data. It has been claimed that open data sharing/hybrid solutions, including crowdsourcing, can create comprehensive, accurate and cost-efficient knowledge bases to support food security (See et al., 2015).

CAPSELLA's impact

Innovation

Multi- or transdisciplinary teams are an essential driver for innovation. This is ensured in the CAPSELLA project through the active involvement and the continuous interaction of several communities and networks working in agriculture, agrobiodiversity, agri-food data innovation, food quality, ICT, 'hackathons', startups and incubation/business support. Their continuous interaction during the project duration will ensure:

- Innovative research impact through the integration and sharing of the best scientific and practical knowledge regarding agrobiodiversity, its applications across the food chain (in informal seed systems, agroecological field management and food quality), and its contribution to sustainability;
- The expression and prioritisation of the innovation issues that communities and networks consider most important regarding (i) agrobiodiversity knowledge, (ii) ICT tools that could foster knowledge sharing, strengthen interactions between various actors within and between communities and channel their message to a wider audience (farmers and their organisations, scientists, agricultural extension services, NGOs, EU, national and regional policy makers, etc.) in a European context, hence demonstrating the capability to reach a critical mass and to transpose the proposed approach to other application areas related to sustainability.

The expected impact above will be further enhanced through the CAPSELLA events, which will allow the project to link with other networks and communities, and also through the opportunity provided by the developed pilots, also tested by other communities.

The core networks represented in CAPSELLA, as well as the extended network of interactions and events between the actors, will ensure the effective involvement of citizens and relevant (and new) actors as well as the establishment of durable interdisciplinary collaborations in concrete application areas related to sustainability.

Having by design a community-driven approach (engagement of communities and networks in building up scenarios and testing the pilots) and a bottom-up methodology for collecting requirements and working on solutions ('hackathons', 'appathons', collective online platforms), CAPSELLA will be able to propose new bottom-up, open and distributed approaches exploiting network effects.

Last but not least, an important asset of the CAPSELLA partners and collaborators is their willingness to participate in open data innovation activities. In fact, several of them are heavily interested in new models of participatory innovation based on open software, open data and open hardware, already having experience in the field. The building of open data catalogues from scratch, based on the networks' and communities' data, and the cloud based platform that will support the development and use of Internet of Things (IoT) applications in the fields, will contribute a great deal to further exploitation of participatory innovation models.

Scientific advancement

CAPSELLA will significantly contribute to opening up the potential of: (a) agrobiodiversity at all levels (genetic, species, habitat and management); and (b) related open data to improve sustainability in the agri-food system. The best knowledge and success stories available from science and practice will be collected from within and outside the expertise of networks and communities, digested in the participatory activities set forth in the scenarios, classified and made available for use by the widest possible range of actors in the European arena through improved ICT solutions and enhanced data open data sets. The ultimate aim of these will be the evidence based understanding of the techno-social issues related to key aspects of the networked society. Results will encompass:

- Bottom-up identification of knowledge gaps and their prioritisation in further research activities at national and EU level, with special emphasis on multidisciplinary issues;
- Archiving of the best solutions using agrobiodiversity at field, farm and landscape scale, clearly showing their effects on the provision of (agro)ecosystem services and their relevance to the sustainability of agri-food systems;
- Awareness raising of citizens on key issues related to the relationships between agrobiodiversity, food quality and (agro)environmental sustainability.

As such, CAPSELLA may have a significant impact in shaping ongoing and future EU agricultural and research policies, and in contributing to all policy and research planning initiatives, as well as further promoting the discussion of sustainability and agriculture.

All the above will be further enhanced by the open data policy adopted for developing and enhancing all CAPSELLA datasets, and the open access policy to all material and publications, including data collected in field trials organised by the pilots, allowing for due consideration of data privacy and ethics.

Society

CAPSELLA will foster the awareness of agrobiodiversity and its importance for (agri)environmental sustainability through bottom-up participatory action supported by targeted, on-demand, novel ICT tools and solutions. Through participatory work in scenarios and pilot trials, CAPSELLA will demonstrate how collaborative approaches using the Internet can offer solutions to societal and sustainability challenges, specifically by making use of the commons, collective problem solving, knowledge sharing, social exchange and community-wide participation at local and global scale. The CAPSELLA data platform is another example of the collaborative approach and knowledge sharing within the project, as it will integrate data from different communities and networks, and include already available registries like CIARD-RING. It will also offer them enhanced support through the use of standards, thus enabling a larger degree of knowledge/data sharing and community participation.

Collective awareness on the importance of agrobiodiversity for sustainability generated in CAPSELLA through the use cases and pilots, and the numerous events and online activities, will ensure scalability, re-usability of results and general applicability of proposed solutions at local or regional level, through the engagement of multiple actors, including regional, national, EU and international networks and policy makers.

Bottom-up priorities and solutions emerging from CAPSELLA will be further voiced to policy bodies in order to support active citizen participation in decision making and collective governance. Incubation activities will lead to the co-creation of new business ideas and opportunities in agriculture and other domains, also the production of new business and economic models, thus ensuring their long-term viability.

CAPSELLA will increase cooperation among citizens, researchers, public authorities, private companies, non-profit, non-governmental and any other civil society organisations around agrobiodiversity and sustainability issues. Improved ICT solutions designed in the scenarios and tested in the pilots and validated by the CAPSELLA communities and networks will foster the development of new sustainable and collaborative consumption patterns and new lifestyles, the creation of innovative products and services, and information delivery.

We are aware of the challenges that they will face throughout the 30 months of the CAPSELLA lifespan. Nevertheless, we do believe that there is momentum in the EU to take up these challenges and to contribute to shaping a biodiversity-based agriculture through new avenues given by co-constructed novel ICT solutions.

References

Armitage, D.R., Plummer, R., Berkes, F., Arthur, R.I., Charles, A.T., Davidson-Hunt I.J., Diduck, A.P., Doubleday, N.C., Johnson, D.S., Marschke, M., McConney, P., Pinkerton, E.W., & Wollenberg, E.K. (2009). Adaptive co-management for social–ecological complexity. Frontiers in Ecology and the Environment (7): 95-102.

Carlsson, L. & Berkes, F. (2005). Co-management: concepts and methodological implications. Journal of Environmental Management 75: 65-76.

Doré, T., Makowski, D., Malézieux, E., Munier-Jolain, N., Tchamitchian, M., & Tittonell, P. (2011). Facing up to the paradigm of ecological intensification in agronomy: revisiting methods, concepts and knowledge. European Journal of Agronomy 34: 197-210.

Gianpietro, M. (2003). Multi-Scale Integrated Analysis of Agroecosystems. Series: Advances in Agroecology. USA: CRC Press. ISBN 9780849310676.

Kaloxylos, A., Wolfert, S., Verwaart, T., Terol, C.M., Brewster, C., & Sundmaeker, H. (2013). The use of Future Internet Technologies in the Agriculture and Food Sectors: Integrating the Supply Chain. Proceedings of the 6th International Conference on Information and Communication Technologies in Agriculture, Food and Environment (HAICTA 2013), 19-22 September.

Kuhlmann, F., & Brodersen, C. (2001). Information technology and farm management: developments and perspectives. Computers and Electronics in Agriculture 30: 71-83.

Schiefer, G. (2004). New technologies and their impact on the agri-food sector: an economist's view. Computers and Electronics in Agriculture 43: 163-172.

See, L., Fritz, S., You, L., Ramankutty, N., Herrero, M., Justice, C., Becker-Reshef, I., Thornton, P., Erb, K., Gong, P., Tang, H., van der Velde, M., Erickse, P., McCallum, I., Kraxner, F., & Obersteiner, M. (2015). Improved global cropland data as an essential ingredient for food security. Global Food Security 4: 37-45.

Tittonell, P. (2014). Ecological intensification of agriculture - sustainable by nature. Current Opinion in Environmental Sustainability 8: 53-61.

Sustainability as a governing principle in the use of agricultural decision support systems: the case of CropSAT

Lundström, C.[1], Lindblom, J.[2], Ljung, M.[3] and Jonsson, A.[4]

[1]Swedish University of Agricultural Sciences

[2]University of Skövde

[3] Swedish University of Agricultural Sciences

[4] Swedish Institute of Agricultural and Environmental Engineering

Abstract: Precision agriculture (PA) is an important part of sustainable intensification, where information and communications technology (ICT) and other technologies are necessary but not sufficient for sustainable farming systems. Many agricultural decision support systems (AgriDSS) have been developed to support farmers to manage an increased amount of gathered data. However, the traditional approach to AgriDSS development is based on the knowledge transfer perspective, which has resulted in technology being considered as an isolated phenomenon and thus not adapted to farmers' actual needs or their decision making in practice. The aim of this study was to improve understanding of farmers' use of AgriDSS. The theoretical framework of distributed cognition (DCog) was used as a lens when investigating and analysing farmers' use of a software tool developed for calculation of variable rate application (VRA) files for nitrogen (N) fertilisation from satellite images called CropSAT. In a case study, the unit of analysis was broadened to the whole socio-technical system of farmer's decision-making, including other people and different kinds of tools and artefacts. The results reveal that CropSAT functions as a tool to support decision making and promotes social learning through the use of *enhanced professional vision*.

Keywords: Precision agriculture, sustainable intensification, distributed cognition, agricultural decision support system, CropSAT, social learning

Introduction

Precision agriculture (PA) is a keystone in a sustainable intensification trajectory where information and communications technology (ICT) and other technologies are necessary for the sustainability of large-scale farming systems (Aubert et al., 2012). By definition, sustainable intensification has to harness the complexity of a wider range of agro-ecological and socio-technological processes and PA is an important piece of the larger picture. PA can be viewed as a management concept based on observing, measuring and responding to within-field variations in both temporal and spatial components. Several kinds of PA technology provide possibilities for crop farmers to recognise and handle variations to a much finer degree than before, and represent a paradigm shift in farming practices due to a change from considering the field as homogeneous to considering it as a heterogeneous entity (Aubert et al., 2012). Better adaptation of field measures to crop requirements decreases sub-optimal treatments, which in turn increases profitability due to higher efficiency in usage of inputs, better crop quality and a decrease in negative environmental impact.

It is widely acknowledged that farming is a complex, dynamic system, involving products and impacts that are difficult to measure, let alone predict and control (Woodward et al., 2008). At the very core of the agricultural transition towards sustainability is the individual decision maker (Matthews et al., 2008; Van Meensel et al., 2012). It should be stressed that it is the individual farmer who makes the strategic, tactical and operative decisions which bridge theory and practice, balancing the desirable with the feasible. It has been argued that various kinds of ICT systems can be a major contributor to the transition towards sustainability in agriculture (Aubert et al., 2012). However, in many of the available agricultural decision support systems (AgriDSS), a certain kind of ICT system developed to support farmers' decision making is for various reasons seldom used to its full potential (e.g. Aubert et al., 2012; Matthews, 2008; Thorburn et al., 2011). Briefly stated, the traditional and normative approach to AgriDSS development is based on the knowledge transfer perspective, which has resulted in many AgriDSS not being adapted to farmers' needs. In particular, Röling (1988) claims that the traditional view lacks a systemic perspective and fails to place the technology in the context where farmers will use it. As a result, available technology can be considered an isolated phenomenon and is therefore often not adopted and situated in farmers' praxis (Röling, 1988).

Based on Röling's (1988) remarks, this study sought to acknowledge the link between environmental sustainability and ICT by addressing *sustainability through design* – how ICT systems in general, and AgriDSS in particular, can be used to promote and cultivate more sustainable behaviours (Hanks et al., 2008; Lindblom et al., 2014). This assumes that PA technologies are instrumental in supporting information-intense decision-making processes that are valuable for agro-ecological systems and for the diversity of farming systems. The overall aim of the study was to improve understanding of farmers' use of AgriDSS. The theoretical framework of distributed cognition (DCog) (Hutchins, 1995) was used as a lens when investigating and analysing farmers' use in practice of a software tool called CropSAT, developed for calculation of variable rate application (VRA) files for nitrogen (N) fertilisation from satellite images. In a case study, the unit of analysis was then broadened to involve the whole socio-technical system of farmers' decision making, including other people and different kinds of tools and artefacts. CropSAT has received much interest from many farmers and it may become an important tool in farmers' adoption of VRA techniques. This study examined how CropSAT functions as a tool to support decision-making processes and promote social learning, which in the long run may create more sustainable farming practices.

Background

Decision-making in agriculture

Farm management and farmers' decision making are usually analysed using theoretical frameworks from economic science (Gray et al., 2009). As a result, the focus is often on the decision event and not on the decision-making process (Öhlmér et al., 1998; Gray et al., 2009; Lindblom & Lundström, 2014). Decision making is a cognitive ability and traditional normative views on cognition in the area of cognitive science have similarities to the normative perspectives on decision making applied in economics, by viewing cognition as the result of internal, individual processes (e.g. Pylyshyn, 1984). However, studies of farmers' decision making in their complex practice have revealed that this kind of description is inconvenient, because it fails to explain decision making in a complex, dynamic and ill-defined context (Gray et al., 2009; Lindblom et al., 2013; Lindblom & Lundström, 2014). Instead, it is important to increase understanding of how farmers actually make decisions, considering their complex socio-technical context, using descriptive theories such as naturalistic decision making (NDM) (Lindblom et al., 2013).

NDM theories emerge from different theoretical and methodological approaches based on decision making 'in the wild', in which studies are performed in situations where humans make decisions in dynamic and complex domains (Klein, 2008). The individual´s experiences and knowledge are taken into account and time pressure and high uncertainty are also included (Orasanu & Connolly, 1995). Although NDM focuses on decision making by experts 'in the wild', the unit of analysis is still only the individual, while contextual factors such as technology and other actors are excluded. According to Lindblom et al. (2013), NDM is an appropriate approach to investigate farmers´ decision making. However, it lacks a systemic perspective within the complex socio-technical system, and therefore the unit of analysis needs to be broadened from the individual to include the social and material context. For this purpose, the theoretical framework of DCog can be a convenient way forward (Lindblom et al., 2013; Lindblom & Lundström, 2014).

DCog: Broadening the unit of analysis

The theoretical framework of DCog was introduced by Hutchins (1995) in response to more individual models and theories of human cognition. From a DCog perspective, human cognition is fundamentally distributed in the socio-technical environment that humans inhabit. DCog takes a systemic perspective and discards the idea that the human mind and its environment can be separated (see Lindblom, 2015 for further details). Hence, DCog views cognition as distributed in a complex socio-technical environment and cognition, including decision-making and learning processes, is viewed as the creation, transformation and propagation of representational states within a socio-technical system (Hutchins, 1995). An important aspect of the systemic view is that cognition is seen as a culturally situated activity that should be studied where it naturally occurs, i.e. 'in the wild'. The DCog framework differs from other cognitive approaches in its commitment to two theoretical principles (Hollan et al., 2000). The first principle concerns the boundaries of the unit of analysis for cognition, which is defined by the functional relationship between the different entities of the cognitive system. The second principle concerns the range of processes considered to be cognitive in nature. In the DCog view, cognitive processes are seen as coordination and interaction between internal processes, as well as manipulation of external objects and the propagation of representations across the system's entities.

When these principles are applied to the observation of human activity *in situ*, three kinds of distributed cognitive processes become observable (Hollan et al., 2000): (1) *Across* the members of a group; (2) *between* human internal mechanisms (e.g. decision making, memory, attention) and external structures (e.g. material artefacts, ICT systems, social environment); and (3) distributed *over* time. Different kinds of representations are central to the unit of analysis in DCog. Hollan et al. (2000) argue that representations should not only be seen as tokens that refer to something other than themselves, but also as being manipulated by humans as physical properties. Hence, humans shift from attending to the representation to attending to the thing being represented. An example used in Hutchins (1995) is the navigational chart, which is used for offloading cognitive efforts (e.g. memory, decision making) to the environment and for presenting information that has been accumulated over time. An important insight in this example is the relationship between the external structure (the chart as a representation) and the internal structure (the biological computation). Hence, by studying the external material and social structures, properties about the internal, mental structures are revealed and become observable. In other words, by studying cognition with this larger scope in mind, it is clear that the functional cognitive system has cognitive properties that cannot be limited to the cognitive abilities of the individual.

Decision support systems (DSS): failure and success factors in AgriDSS

A DSS is an ICT system that supports either a single decision maker or a group of decision makers in making more effective decisions when dealing with unstructured or semi-structured problems. The DSS supports one or more activities in a decision-making process in order to complement and 'support' decision makers rather than to replace them. Furthermore, a DSS can either support the decision maker in an ongoing decision situation, or it can prepare the decision maker to perform better in the future through decision training (Alenljung, 2008). By using a DSS, individual productivity, decision quality and problem solving can be improved and interpersonal communication and learning can be facilitated. In addition, using a DSS can improve decision-making skills and increase organisational control (Alenljung, 2008).

The main efforts made to bridge the gap within the current agricultural knowledge and innovation system (AKIS) include implementing new advisory concepts, re-organising advisory services and developing AgriDSS. Many AgriDSS have been developed, but not used to any wider extent, mainly as a result of the normative way of development based on the perspective of knowledge transfer, where knowledge is produced by research and end users are looked upon as passive receivers (e.g. McCown, 2002; Matthews, 2008; Thorburn et al., 2011; Aubert et al., 2012). Accordingly, there is a need for functional and usable AgriDSS that promote sustainable farming practices by providing proper and credible representations of complex situations that clarify and support farmers' decision making without losing the complexity at hand. An AgriDSS must therefore match farmers' naturalistic decision making and challenge their learning without replacing their 'gut feeling' (Hochman & Carberry, 2011). In addition, it has to support farmers' experimentation with options rather than present optimal solutions, because when farmers are handling messy, real-world problems they tend to satisfy current needs rather than optimising performance. Many researchers point out that an AgriDSS is a useful tool for the ongoing transfer of scientific knowledge and 'best practices', claiming that the single unifying predictor of success or failure is the extent to which users are involved and participate in the design and development processes of the AgriDSS (e.g. Woodward et al., 2008; Jakku & Thorburn, 2010; Hochman & Carberry, 2011; Van Meensel et al., 2012). Another important aspect of participation approaches is social learning among stakeholders involved in the development and use processes (e.g. Jakku & Thorburn, 2010; Hochman & Carberry, 2011).

Method and performance

The case study

During spring 2015, a *workplace study* was performed (Luff et al., 2000). The study adopted a qualitative approach, using ethnographical data collection techniques, and the collected data were triangulated from participant observation, video-recordings and semi-structured interviews. The study was conducted with four purposively sampled farmers in western Sweden. The selected farmers had previous experience of using ICT-based crop production software (CPS) and demonstrated an interest in PA technology.

Setting the scene

During 2013-2014, a new AgriDSS for N fertilisation, CropSAT (www.cropsat.se), was developed by the Precision Agriculture Sweden (POS) network (www.precisionsskolan.se/). CropSAT uses satellite images for calculation of vegetation index (VI) (Qi et al., 1994) and VRA files for N fertilisation in cereals. During 2015, a high-fidelity prototype of CropSAT was made available on the internet for use, free of charge, thanks to funding by the Swedish Board of Agriculture. To support farmers in their N fertilisation strategy, a minimum of three satellite images were published during the period April-June 2015. The recommended strategy for fertilising wheat is to apply N two or three times during spring (Albertsson et al., 2015).

To calculate a VRA file in CropSAT, the user visits its website and selects a field and a satellite image. As a result, the VI is calculated and shown in Google Maps. To receive a VRA file, the user must decide the level of N fertilisation within five VI classes, which are estimated automatically from the satellite data (Figure 1a) and used to calculate VRA files for N for the field. The VRA information is transferred to the tractor and spreader via a USB stick.

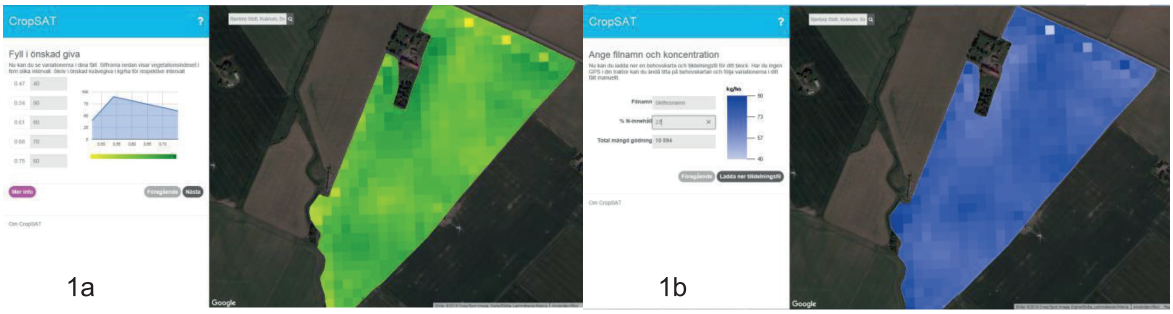

Figure 1. a) Vegetation index is displayed on Google Maps, where the user should enter five levels of N fertilisation compared with the coloured scale. b) VRA file ready to be entered into the fertiliser spreader via a USB memory stick.

To set the N levels for each VI class, the user is recommended to go out into the field and verify the N status with a so-called Spadmeter (https://www.konicaminolta.eu/en/measuring-instruments/products/colour-measurement/chlorophyll-meter/spad-502plus/introduction.html), or to simply estimate the need for additional N, based on observation of the canopy and prior experience. When new satellite images were published during spring 2015, the farmers studied the crop development on the actual farm using

CropSAT. On some occasions, a VRA file was calculated and later used for variable fertilisation, and sometimes the images were used to get an overview of the status, or used in the decision-making processes regarding fertilisation with a Yara N-Sensor (YNS) (http://www.yara.se/crop-nutrition/Tools-and-Services/n-sensor/).

Findings: CropSAT used 'in the wild'

Swedish farmers fertilise winter wheat one to three times during spring in order to optimise yield and protein content. They have a fertilisation plan for each field, and in this study all farmers used an ICT-based CPS for creating these plans. In the fertilisation plan, an average amount of N per field is specified, but can be adjusted due to a wide range of factors during the season. Farmers can use CropSAT or some kind of tractor-based N sensor to apply a variable rate of fertiliser, using the planned average amount of N as a basis. The units of analysis in these decision-making processes include a wide range of artefacts, e.g. CropSAT (images on VI and VRA files used in computers, mobile phones and iPads), CPS (tables and field maps in computers, mobile phones and iPads), paper-based field maps, calculator (in mobile phone), Spadmeter and notepads (Figure 2).

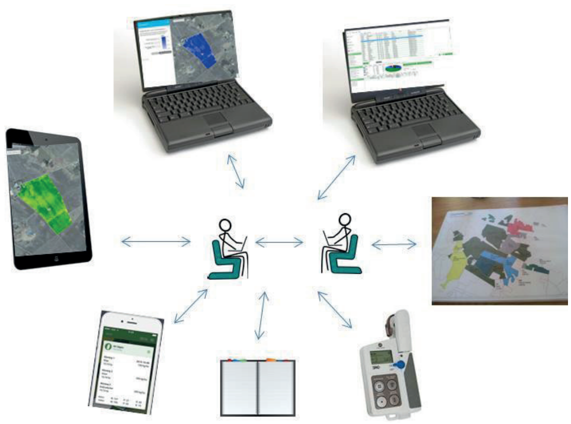

Figure 2. Unit of analysis of the DCog system, where cognitive processes are distributed: (1) *across* the members of a group, (2) *between* human internal mechanisms (e.g. decision-making, perception, memory) and external structures (material artefacts, ICT systems and social environment), and (3) *over* time.

The images created in CropSAT are visual digital representations that display crop biomass complexity in a way that is difficult to achieve by walking or driving in the field. Below, descriptions and analyses of some selected brief episodes that illustrate decision-making processes within the distributed cognitive system are presented. In the first episode, CropSAT is being used as a decision support tool for calculation of VRA files. In the second, CropSAT is being used as a coordination mechanism in the decision-making process for crop production.

CropSAT as a decision support tool for creation of VRA files

It is widely recognised that farmers know that crop yield varies within fields. When looking at the satellite images in CropSAT, farmers with long experience of their own fields easily recognise and explain much of the visualised variation in crop biomass. In this particular episode, an experienced farmer in his 50s using CropSAT for the first time took a closer look at one of his fields of winter wheat. He had 15 years of experience of using VRA files and YNS. He compared and contrasted his acquired knowledge of the characteristics of the particular field with the satellite image displayed in CropSAT. He then said: "*Well, this [field] is a bit poorer, you could say ... it's farther away from the old farmhouse, so over time it almost certainly got less manure, and besides the soil is lighter up here. So it looks like I expected... I could have drawn [the map] myself".*

It should be noted that the bird's eye view of the variation in crop biomass is difficult to observe while merely walking in the field. Consequently, fertilising correctly with regard to variations in the field is impossible without support from technology. The CropSAT image provides another kind of representation format that visualises the within-field variation with more clarity than could be achieved with the human vision system alone. As such, the image reveals details and differences that the *professional vision* (Goodwin, 1994) of an experienced farmer cannot "see" clearly due to biological characteristics of the human colour vision system. *Professional vision* is a socially organised way of seeing and understanding events that are of interest in the domain and to the social group (Goodwin, 1994). The major challenge is that the farmer has to act upon this variability by setting the five levels of N fertilisation in relation to the variation in crop biomass.

Figure 3. Telephone support to set N levels in CropSAT. The farmer pointed at the image while speaking to his advisor.

In the next episode, a younger, university-educated farmer with shorter farming experience had some difficulties in grasping how to use the CropSAT images. He had recently invested in PA technology in his farming business and he was a skilled user of various ICT systems. In the particular episode described here, he was re-planning the amount of N fertilisation in a particular field with winter wheat. He had previously set the average level to a standardised amount together with his advisor in the CPS. It is obvious that deciding on the five levels of N in practice was not an easy task for him and therefore he needed some assistance from his advisor. He phoned his advisor and the conversation went as follows: "*Hi ... we're sitting here with the files for variable rate application and vegetation index and I'm wondering about what doses to use, or how much I should vary it ... for wheat ... yes the main dose for wheat is given as 80 kg N per hectare and then ... yes, you get a beautifully coloured map, but the question is how much variation you need to use".*

During the discussion, the farmer repeatedly pointed to different aspects on the screen, e.g. N levels, the VI scale or different parts of the field (Figure 3). He and the advisor had a long and intense discussion concerning how to set the five levels of N. CropSAT challenged his common work practice, i.e. fertilising with the same amount throughout the whole field or using the YNS. When his work practice altered, he was hesitant about deciding the levels and sought support from his advisor. In this episode, the satellite image ceased being a representation of the field and became the field itself. The information provided by the image was shared between farmer and advisor and functioned as a coordination mechanism in their conversation. After the call, the farmer decided the fertilisation levels on three additional fields and calculated VRA files to be used on the same day. It should be emphasised that the guidance received from the advisor supported the farmer in deciding the N levels for the other fields, but he was still not confident concerning his way of reasoning about the fertilisation strategy.

CropSAT as a coordination mechanism in the decision-making process for crop production

In these two episodes, an experienced farmer in his 50s was initially discussing fertilisation with his advisor. The first episode started after they had been walking in the fields and were sitting in the farm canteen to discuss the current situation and the decisions to be made. They used CropSAT to get an overview of the fields and compare the satellite images displayed with their first-hand experiences of the fields. As shown in the first episode above, they had some difficulties in interpreting the satellite images, which resulted in intense discussions (Figure 4).

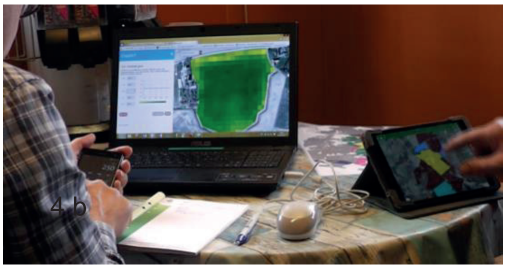

Figure 4 a) Discussions about within-field variation in crop biomass due to soil compaction at the first meeting; b) Different tools and artefacts used in the distributed cognitive system.

In the next episode, the task was to decide how to fertilise seven fields of winter wheat. Instead of using CropSAT to calculate VRA files, the intention was to use the YNS to spread N. The motivation for this way of working was that YNS provides a more detailed picture of the biomass variation and consequently the amount of N can be distributed more precisely. During this meeting, all tools and artefacts displayed in Figure 4b were available and the satellite image taken three weeks earlier was used for comparing how much N had been utilised by the crop. Before the meeting, the advisor had used a Spadmeter in the fields to measure the need for additional N fertilisation based on the canopy greenness. These measurements were used as a point of reference in the ensuing discussion.

The role of the advisor is of major importance when introducing new technology in advisory services. In this particular case, the advisor acted as a role model in his ways of using the available tools and artefacts, advocating a ‘willing and able’ approach that influenced the farmer. However, the different digital representations of the fields in various ICT systems offered additional, but artificial, perspectives on the fields that differed significantly from first-hand experiences when walking in the fields. The key question was how to correctly utilise and combine the different representations and the acquired tacit knowledge, in order to develop a more sustainable farming practice.

The available digital representations from CropSAT initiated new kinds of discussions about the fields and current farming practices that were not possible previously due to the lack of detailed representations of with-in field variation in biomass at the time of fertilisation planning. The only option available previously to obtain an overview of the field was to walk through it or to measure with-in field variation in biomass with some kind of field sensor (but without fertilising). However, the enhanced detail in the digital representations, that was available with less effort than using a field sensor, triggered and facilitated comparisons between different factors, e.g. VRA files for phosphorus fertilisation and the satellite image. For example, the farmer and advisor discussed how variation in soil characteristics and phosphorus values could explain the with-in field variation in biomass. The farmer said: *"We used that variable rate application file last year there. We fertilised according to P content with it. I am so fascinated by this, it's completely insane*". On the one hand, the new digital representations provided more detailed information than before, which in turn provided additional support for making decisions regarding fertilisation. On the other hand, the additional information may result in a more complex decision-making process, since the farmer lacks prior experience of how to interpret and use the added information, i.e. the digital representations have to be interpreted, compared and situated in the farmer's decision-making context, resulting in an ongoing social learning process involving both practitioner and advisor. In other words, the perspective of *professional vision* is intensified through the so-called process of *tool-mediated seeing* (Goodwin & Goodwin, 1996). *Tool-mediated seeing* is characterised as seeing aspects relevant for a task only through the use of tools and artefacts, i.e. the satellite images in CropSAT. In this particular situation, this was done through interpreting the digital representations of the within-field variations in biomass.

Let us now return to the decision on how to decide the average amount of N and then calibrate the YNS to fertilise winter wheat for the last time in the spring. CropSAT offers the possibility of comparing and discussing the development of the crop and its N uptake in relation to earlier fertilisation. In order to accomplish these tasks, the farmer and advisor first compared the earlier satellite image with the current image, discussing intensively how to interpret the images and then explaining what has happened in the field (Figure 5). They agreed that the crop had developed satisfactorily and that the winter wheat fields were looking good.

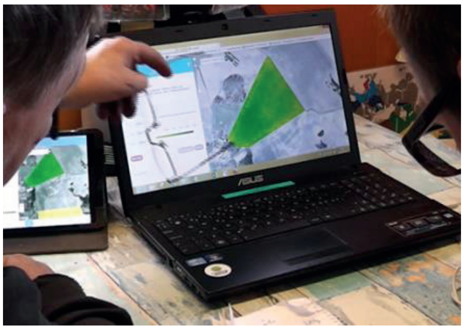

Figure 5. The farmer explaining differences in biomass variation between two different images, an older image on the left side and the present image on the right.

Based on the planned amount of N in the CPS, the measurements from the Spadmeter, earlier first-hand experiences and the satellite images (both older and present), the farmer and advisor decided the average amount of N for each field. In order to calibrate the YNS, the advisor pointed at the screen displaying the satellite image and then showing where to drive the tractor to cover the variation in crop biomass (Figure 6). Calibrating the YNS is not an easy task without support from the ICT system because it is necessary to select appropriate spots to optimise the calibration.

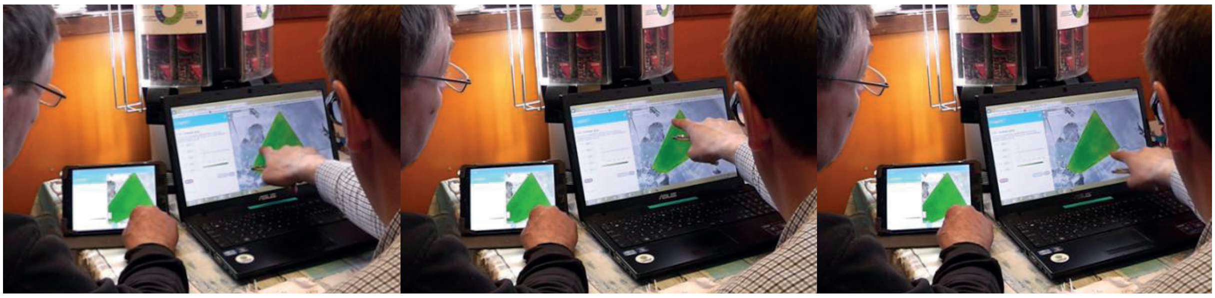

Figure 6. Image sequence where the advisor (right) is making a suggestion on where to drive the tractor to calibrate the YNS to grasp the within-field variation in biomass.

This example illustrates how the participants explored new ways of using the available technology, e.g. CropSAT and YNS. This involved using the CropSAT images as a means to calibrate the YNS, which was not the intended contribution of CropSAT. Although this usage of CropSAT was beyond the developers' intention, it still contributed to generating sustainable farming practices through ongoing learning processes. Thus, it can be claimed that the ICT systems function as social learning tools. Taken together, this adds another dimension to Goodwin's (1994) initial term *professional vision* and Goodwin's and Goodwin's (1996) term *tool-mediated seeing*, which can be denoted *enhanced professional vision.* This *enhanced professional vision* incorporated both the above terms, because these need to be combined when making decisions on the use of ICT support and tacit knowledge in PA.

The examples above show socially distributed cognition over time and how the whole socio-technical cognitive system, which in this case would include farmers, advisors and the available tools and associated artefacts, is capable of performing much more than the individual farmer could. In other words, the coordination of different representations (external and internal) is an emergent property of the system as a whole, not easily reduced to an evident property of a certain entity (human or artefact and tool). This systemic view is the central foundation of the DCog approach; the whole is more than the sum of the individual parts, as the whole socio-technical system demonstrates emergent properties. Thus, cognition is viewed as *creation*, *transformation* and *propagation* of *representational states* within a socio-technical system (Hutchins, 1995).

Discussion and Conclusions

This study sought to characterise and illustrate the use of CropSAT in PA as a complex socio-technical system from a distributed cognition perspective, focusing on the use, mediation and integration of different forms of representations, tools and artefacts in this domain to improve understanding of farmers' use of AgriDSS. The results revealed how CropSAT functions as a tool to support decision-making processes and promote social learning, which in the long run may generate more sustainable farming practices through the use of an *enhanced professional vision*. It is evident that an AgriDSS such as CropSAT provides important information that could be used as a basis for learning about farmers' crop fields as a part of a larger learning system. The advisor has a central role in promoting the usage of different ICT systems to support and foster social learning processes about how to fertilise farmers' fields, which is a governing principle in the direction that we envision for sustainable farming.

The interest shown by both farmers and advisors indicates that CropSAT is an AgriDSS that shows potential to fit within PA. However, new technology needs novel social and organisational arrangements, such as rules, perceptions, agreements, identities and social relationships to function properly (Leeuwis & Aarts, 2011). Thus, advisory services have a central role to fulfil, to situate the ICT systems in the context of their usage, where they provide opportunities to be used to a wider extent than just for the calculation of VRA files. Thus, technology should not be considered an isolated phenomenon in PA, as pointed out by Röling (1998). There are also possibilities for the use of CropSAT leading to change in current farming practices from their goal orientation to a learning orientation, which in itself has been a much discussed theme within advisory work. Although some farmers are reluctant to use ICT, and instead *'rely heavily on intuitive judgment underpinned by experience'* (McCown, 2002), this study showed that more detailed representations of their fields provide added value. We therefore introduced the term *enhanced professional vision* to characterise the combination of *professional vision* and *tool-mediated seeing*.

The implication of this study is that CropSAT should be considered part of a wider AKIS, where different kinds of ICT systems, tools, artefacts and social learning processes constitute additional parts of the system. CropSAT provides a 'hardware' that still needs further improvement of the 'software', but the immature 'orgware' requires additional development and discussion. Once this has been achieved, we envision that CropSAT could be an important component in the trajectory of sustainable intensification in agriculture and enhance the professional vision of farmers.

Acknowledgements

We wish to thank the farmers and advisors who let us take part in their daily practice and gave their permission for publication of the illustrations. This work was financially supported by the thematic research programme Biological Soil Mapping (BioSoM) at NJ Faculty, Swedish University of Agricultural Sciences. We also wish to thank the CropSAT developers M. Söderström, K. Nissen and H. Stadig, as well as Dataväxt AB.

References

Albertsson, B., Börling, K., Kvarmo, P. Listh, U. Malgeryd, J., & Stenberg, M. (2015). Rekommendationer för gödsling och kalkning 2016. Jordbruksverket. JO15: 19.

Alenljung, B. (2008). Envisioning a future decision support system for requirements engineering. Doctoral Thesis, Linköping University, Sweden. Thesis No. 1155.

Aubert, B. A., Schroeder, A., & Grimaudo, J. (2012). IT as enabler of sustainable farming. Decision Support Systems, 54(1): 510-520.

Goodwin, C. (1994). Professional vision. American Anthropologist 96(3): 606-633.

Goodwin, C., & Goodwin, M. H. (1996). Seeing as situated activity. In: Y. Engeström and D. Middleton (Eds.) Cognition and Communication at Work pp. 61-95. Cambridge, UK: Cambridge University Press.

Gray, D. I., Parker, W.J., & Kemp, E. (2009). Farm management research. Journal of International Farm Management 5(1): 1-24.

Hanks, K., Odom, W., Roedl, D., & Blevis, E. (2008). Sustainable Millennials. In Proceedings of CHI 2008, New York, US: ACM.

Hochman, Z., & Carberry, P.S. (2011). Emerging consensus on desirable characteristics of tools to support farmers' management of climate risk in Australia. Agricultural Systems 104(6): 441-450.

Hollan, J., Hutchins, E., & Kirsh, D. (2000). Distributed cognition: toward a new foundation for human-computer interaction research. ACM Transactions on Computer-Human Interaction 7(2): 174-196.

Hutchins, E. (1995). Cognition in the Wild. Cambridge, US: MIT Press.

Jakku, E., & Thorburn, P.J. (2010). A conceptual framework for guiding the participatory development of agricultural decision support systems. Decision Support Systems 103(9): 675-682.

Klein, G. (2008). Naturalistic decision making. Human factors. The Journal of the Human Factors and Ergonomics Society 50(3): 456-460.

Leeuwis, C. & Aarts, N. (2011). Rethinking communication in innovation processes, The Journal of Agricultural Education and Extension 17(1): 21-36.

Lindblom, J. (2015). Embodied Social Cognition. Berlin: Springer Verlag.

Lindblom, J., & Lundström, C. (2014). Lantbrukares beslutsfattande och lantbruksrådgivning - en förstudie. Department of Soil and Environment, Report, 15:2014. Swedish University of Agricultural Sciences.

Lindblom, J., Ljung, M., & Lundström, C. (2014). Next Generation Decision Support Systems for Farmers: Sustainable Agriculture through Sustainable IT. Proceedings of the 11th

International Farming Systems Association Symposium (IFSA 2014), April 1-4 2014, Berlin, Germany.

Lindblom, J., Rambusch, J., Ljung, M., & Lundström, C. (2013). Decision Making in Agriculture. Farmers' European Seminar on Extension Education, 2-6 September, Antalya, Turkey.

Luff, P., Hindmarsh, J., & Heath, C. (2000). Workplace Studies. Cambridge: Cambridge University Press.

McCown, R.L. (2002). Changing systems for supporting farmers' decisions. Agricultural Systems 74(1): 179-220.

Matthews, K.B., Schwarz, G., Buchan, K., Rivington, M., & Miller, D. (2008). Wither agricultural DSS? Computers and Electronics in Agriculture 61(2): 149-159.

Öhlmér, B., Olson, K., & Brehmer, B. (1998). Understanding farmers' decision making processes and improving managerial assistance. Agricultural Economics 18(3): 273-290.

Orasanu, J., & Connolly, T. (1995). The reinvention of decision making. In: G. Klein, J. Orasanu R. Calderwood and C. Zsambok (Eds). Decision Making in Action. New Jersey: Norwood.

Pylyshyn, Z.W. (1984). Computation and Cognition. Cambridge, MA: MIT Press.

Qi, J.G., Chehbouni, A., Huete, A.R., Kerr, Y.H., & Sorooshian, S. (1994). A modified soil adjusted vegetation index. Remote Sensing of Environment 48(2): 119-126.

Röling, N.G. (1988). Extension Science. Cambridge: Cambridge University Press.

Thorburn, P.J., Jakku, E., Webster, A.J. & Everingham Y.L. (2011). Agricultural decision support system facilitating co-learning. International Journal of Agricultural Sustainability 9(2): 322-333.

Van Meensel, J., Lauwers, L., Kempen, I., Dessein. J., & van Huylenbroeck, G. (2012). Effect of a participatory approach on the successful development of agricultural decision support systems: the case of Pigs2win. Decision Support Systems 54(1): 164-172.

Woodward, S.J.R., Romera, A.J., Beskow, W.B., & Lovatt, S.J. (2008). Better simulation modelling to support farming systems innovation. New Zealand Journal of Agricultural Research 51(3): 235-252.

Experiments on the use of knowledge management tools for agriculture

Soulignac, V. [1], Pinet, F. [1], Vallas, M. [2] and Ermine, J.-L. [3,4]

[1] *Irstea (National Research Institute of Science and Technology for Environment and Agriculture), France*

[2] *Pôle Agriculture Biologique Massif Central, France*

[3] *Président du Club de Gestion des Connaissances, France*

[4] *Telecom Ecole de Management, France*

Abstract: Agriculture must be both sustainable and economically viable. Sustainable agriculture requires new knowledge and expertise. However, knowledge management is not sufficient in current sustainable agriculture. To overcome this, we have made the assumption that the knowledge management practices used in industry can be transferred to agriculture. In this paper, we propose to apply to agriculture, the methodological tools developed by the French knowledge management group. These tools are based on theoretical approaches for the transformation of explicit and tacit knowledge within an organisation. These tools are generic and suitable for any knowledge. We have tested the tool CFK for knowledge criticality in order to identify the knowledge to make explicit within a farm. This knowledge is critical because it is valuable, rare, complex and difficult to formalise. It must therefore be managed. We have determined the criticality of knowledge in a farm for organic agriculture field crops, in prairies and on various flora grain legumes. In the French research project TATABOX, related to the agro-ecological transition study in an area between Tarn and Aveyron in France, we have also experimented with another methodological tool (TRACO) for characterising the most appropriate knowledge transfer tools to use between an agricultural cooperative and farmers. Among 16 knowledge transfer methods proposed, TRACO allows highlighting of supervised self-education but also traditional teaching courses, communities of practice and workshops. Our conclusion is that the proposed knowledge management tools seem relevant to manage knowledge in agriculture, but they still require training and adaptation to the agricultural field.

Keywords: Agro-ecology, knowledge management tool

Introduction

Agriculture must become more environmentally sustainable while being economically viable. Taking better account of ecosystems, this type of agriculture called agro-ecology is the inverse of an intensive agriculture. The production and acquisition of knowledge by farmers is one of the strategic conditions to develop this sustainable (but productive) farming. Currently, knowledge for productivity improvement is available, but knowledge that meets requirements for environment, territory and economic viability must be developed. Therefore, agro-ecology requires new knowledge and expertise. The diversity of the stakeholders and the difficulty of performing experiments because of the long duration of the production cycles constitute obstacles to knowledge capitalisation. Thus, current knowledge management is not sufficient in agro-ecology (Meynard, 2012; Guichard et al., 2015). To remedy this problem, we make the assumption that knowledge management methods applied in the industrial world can be transposed to agriculture (Soulignac, et al., 2012). This paper focuses on the methodological tools developed by the French knowledge management group ("Le club de gestion des connaissances" - http://www.club-gc.asso.fr/accueil_gc). These tools are based on the transformation of explicit and tacit knowledge within organisations (Nonaka & Toyama, 2003; Ermine, 2008). They are generic and usually suitable for any type of organisation. In this paper, we present the use of two of these tools in real cases in agriculture. The first tool is used to identify the "critical" knowledge on which organisations should focus. The second tool allows the organisations to better define the knowledge transfer to be implemented.

Knowledge management

The creation of explicit knowledge in an organisation is a complex task. The knowledge management process involves a first step to identify the most important knowledge (called critical knowledge). The second step is the definition of an action plan to reduce risks related to a poor control of knowledge. There are two main action types. The first type of action plan is skills management. Knowledge is transferred by people, via learning processes or through recruitment. The second type of action is indirect. It requires a phase in which explicit knowledge is written, before a step of knowledge appropriation. Since the early 2000s, the French knowledge management group has developed a methodology for knowledge management. At each step of this methodology, the group proposes the use of a software tool, as indicated in Figure 1. Each of these tools uses the results of surveys conducted among stakeholders in the studied areas. It is not always necessary to use all the tools. For example, an organisation can choose to successively use the following tools:

- The tool called CKF for evaluating the criticality of knowledge;
- The decision support system TRACO to identify the most relevant knowledge transfer methods;
- The RPC guide for writing knowledge, if indirect knowledge transfer is an appropriate solution.

All these tools have been extensively used in industry in France, by private companies or public institutions. Their interest was proven in industrial and service activities. These tools are generic, as they are suitable for any of these areas, but a question arises about the usability of these tools for knowledge management in agro-ecology; this latter area having certain particular characteristics. For example, agro-ecology implies an anticipation strategy to manage pests. In this context, a crop rotation over a long period, more than five years, can be considered and implemented in order to limit the occurrence of plant diseases or weeds. Local characteristics are very important, in particular the soil and climatic conditions make the production of knowledge to design a rotation taking into account different issues (pests, production, etc.) complex. Efficient solutions to be implemented locally are often the result of a combination of both empirical and scientific knowledge. The challenge is to determine if these tools also provide a solution for complex cases in which different types of knowledge must be combined, according to their origins (e.g., operational and scientific knowledge).

We experimented with the use of the methodology described in Figure 1 in several projects in organic farming or agro-ecology. In this paper, we report the feedback on the experience of using two knowledge management tools described above i.e. the tool for critical knowledge CKF and the decision support tool TRACO for knowledge transfer.

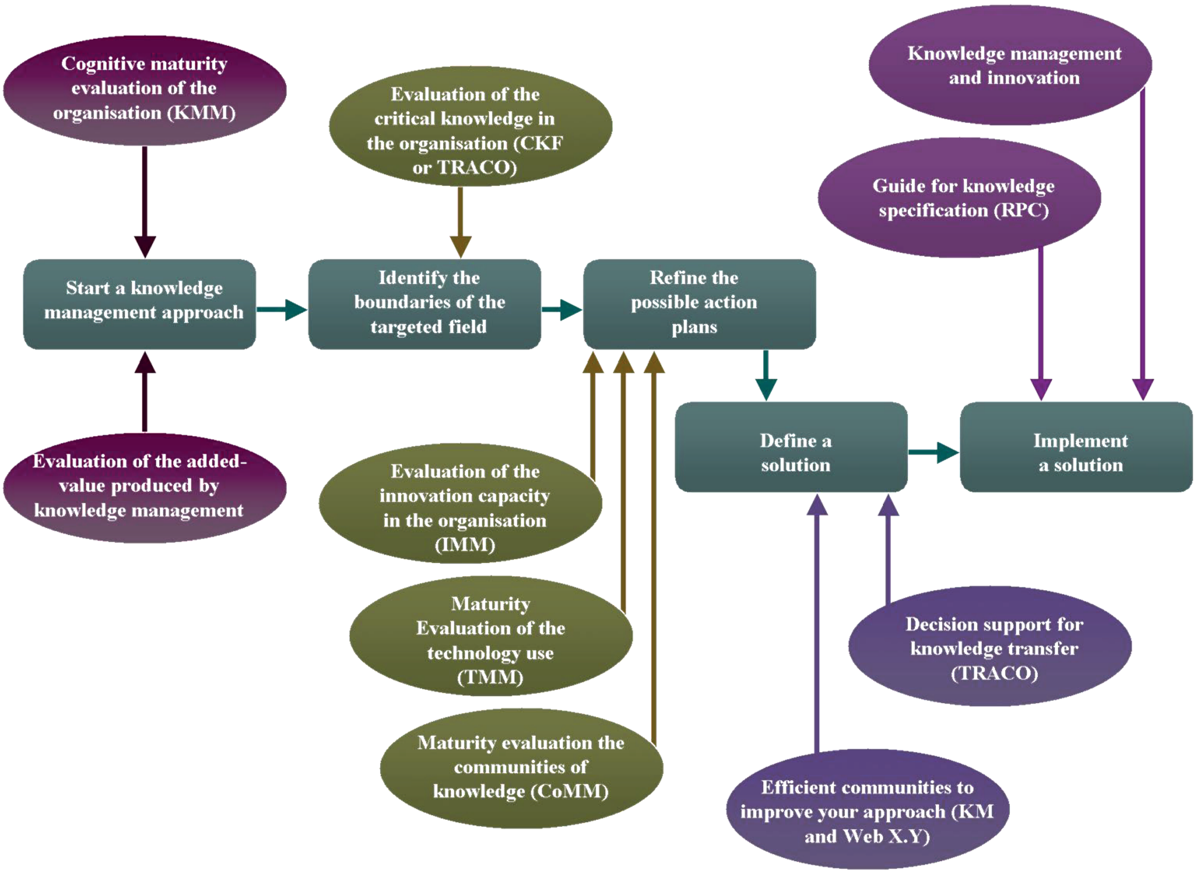

Figure 1. Methodology for knowledge management (by the French knowledge management group – "club de gestion des connaissances" - http://www.club-gc.asso.fr)

Use of knowledge management tools in agriculture

CKF – a tool for knowledge criticality

CKF enables the identification of critical knowledge (Club de gestion des connaissances, 2004). Factors having an impact on this criticality are the knowledge usefulness, its rarity, its complexity and the difficulty of implementation. We tested CKF in multiple environments including the Melibio project led by the Organic Agriculture Centre for Massif Central in France. This research and development project aims at enhancing the diversity of species, forage varieties and farming practices in organic farming in order to secure the food systems of ruminants in Massif Central in France. This project involves researchers, agricultural advisors, experts and teachers. In this paper, we illustrate the use of CKF on an example of research work related to the varied plant prairie management, conducted in the Melibio project. The CKF method includes several steps:

- Agricultural advisors and researchers having knowledge in varied plant prairies in organic farming were chosen. We could also involve farmers ;
- The knowledge areas are defined collectively. They are as disjoint as possible in order to facilitate their analysis. Thus, 23 knowledge areas on varied plant prairie management have been identified related to pest management or nutritional needs of animals, etc. The complete list is shown in Table 1;
- Each of these areas is rated by an expert according to the four criteria (usefulness, rarity, complexity, implementation difficulty). A high score means that the knowledge area is highly critical.

The knowledge areas are ranked from #1 (the most important) to #23 (the least important). The results are presented in Table 1.

Table 1. Criticality knowledge ranking related to the management of varied plant prairie (5-10 year plant) in organic agriculture

N°	Topics	Knowledge fields
1	Development strategy of the forage system	Varied flora prairie destruction
2	Technical action	Fertilisers
3	Development strategy of the forage system	Socio-economical factor
4	Development strategy of the forage system	Role of varied flora prairie in crop rotations
5	Technical action	Control of bioagressor and disease
6	Development strategy of the forage system	Pedoclimatic knowledge
7	Development strategy of the forage system	Animal needs
8	Technical action	Harvesting and storage method
9	Environment	Water
10	Technical action	Agricultural seeding
11	Plant dynamics	Dry matter
12	Environment	Landscape
13	Technical action	Control of bioagressor and weed
14	Technical action	Control of bioagressor and pest
15	Technical action	Location
16	Environment	Carbon footprint
17	Plant dynamics	Quality
18	Environment	Biodiversity
19	Development strategy of the forage system	Floristic composition of varied flora prairie
20	Development strategy of the forage system	Forage system adaptation
21	Development strategy of the forage system	Role of varied flora prairie in forage system
22	Plant dynamics	Diversity
23	Plant dynamics	Sustainability

The project Melibio commenced in 2011 and will finish in 2018. The methodological tool CKF was applied to the varied plant prairie management from the beginning of the project. The result analysis highlights the priority areas, but also those in which cognitive investment is not needed. Thus, subjects such as fertilisation or disease treatment will not be studied in Melibio because these technical processes are well controlled. Subjects related to plant dynamics such as varied plant prairie diversity and sustainability are preferred. Detailed analysis of the results facilitates the creation of an action plan. The rating of the four factors (usefulness, rarity, complexity, implementation difficulty) is analysed, but also the differences between the opinions of researchers and agricultural advisors:

- Each CKF rating of factors refer to an action plan:
    - When the usefulness factor rating is low, even if the overall score is high, the question about the relevance of the field study is raised. Consequently, the pest control is not taken into account.
    - When a domain is rare, i.e. only little knowledge is associated with it, then a scientific research work or an empirical knowledge collection is started, as was the case with plant dynamics.
    - When a domain is complex but its implementation is relatively well controlled, a wiki web server is a possible solution to explain and disseminate knowledge.
    - When the difficulty factor has a high rating, a pilot plot is used to identify good practices over a long period and for their dissemination through farmer meetings.
- The level of knowledge in a domain between agricultural advisors and researchers is sometimes different. Consequently, the ratings can be different. In our analysis of ratings, we distinguish agricultural advisors and researchers. For a researcher, information is rare when there is a limited number of scientific publications about the topic. For an agricultural advisor, information is rare when it cannot be found in practical cases. This point can explain some differences in ratings. In that case, the knowledge transfer is possible. For instance, concerning the carbon footprint issue, courses can be created to transfer knowledge related to carbon footprint. Knowledge transfer can also be produced by technical actions. In this case technical skills can be transferred to researchers ; as is the case for example for the methods used in practice for varied plant prairie harvesting and storage.

TRACO – a decision support tool for knowledge transfer

The methodical tool TRACO allows choosing of the best approaches. TRACO offers 16 knowledge transfer methods (Club de gestion des connaissances, 2009), classified into four types:

- "Classroom" training courses where the trainer and the trainees are physically in the same room.
- Methods mixing practical and theoretical knowledge such as block-release training.
- Knowledge transfer media such as knowledge server software dedicated to knowledge dissemination.
- Knowledge networks in which people can share and enrich their practices (such as communities of practices).

28 criteria are used to choose an appropriate transfer method. These criteria are divided into four main types:

- The deadlines / urgency of knowledge transfer and the contextual information.
- The nature of knowledge.
- The source, i.e. the holders of the knowledge.
- The target, i.e. the receivers of this knowledge.

For each of the 16 transfer methods proposed by TRACO, each 28 criteria is evaluated according to a colour code:

- The "red" colour is used when the method is not recommended.
- "Yellow" if the method is partially adequate.
- "Green" when the method is adequate.
- The “White” colour means that the criterion has no influence on the method analysis.

We take an example of the analysis of the classroom training course method for the factor of knowledge integration difficulty for one person. As shown in Figure 2, a classroom training course is appropriate when knowledge can easily be integrated in the practices.

We have 28 criteria to be applied to each of the 16 knowledge transfer systems. Consequently, we study 448 results to determine the most appropriate actions. Of course, the systems that have the greatest number of "green" colours will be preferred for the studied organisation. In the French project called TATABOX (funded by the Research National Agency - ANR) on the agro-ecological transition, we experimented with TRACO to determine the most appropriate knowledge transfer tools to use between an agricultural cooperative called Qualisol and its farmers. Qualisol is a pioneer cooperative in agro-ecology in the Southwest of France. The development of grain legumes (beans, lentils, chickpeas, etc.) completely complies with the objectives of Qualisol and this agro-ecological transition project. In addition to their nutritional qualities, grain legumes have also very good agronomic properties. Their cultivation provides nitrogen to the soil. The decrease in the use of fertilisers reduces both health and environmental impacts of nitrogen inputs (Projets ANR LEGITIMES ET TATABOX, Ecole d'ingénieurs de PURPAN et al., 2015; Soulignac et al., 2015). Magrini et al. (2014) show that the development of grain legumes implies technological problems. The solutions are the definition of actions of knowledge capitalisation and dissemination conducted by research, teaching and advisory organisations. To transfer knowledge on grain legumes, the Qualisol cooperative needs to use the most appropriate tools. Purpan engineering school students (France) conducted a survey of the Qualisol chief agronomist. The result is shown in Figure 3. Over the 16 transfer methods, TRACO allows us to highlight independent learning, but also “classroom” training courses, knowledge networks and workshops.

Degree of difficulty of using this knowledge in practice: (1) Knowledge can be used without experience ; (3) Knowledge requires experience	**1 Easy to use in practice**	**2**	**3 Very difficult to use in practice**

Figure 2. One example of a ranking proposed for the criterion 'knowledge usability for one person' and for the method 'classroom training course'

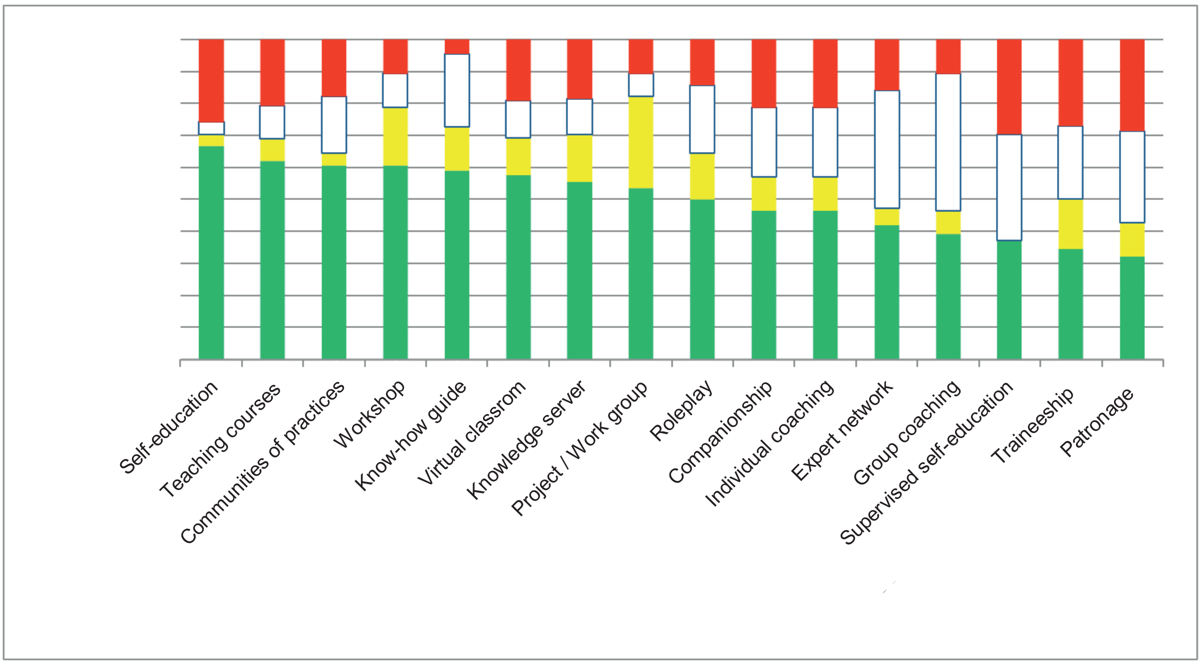

Figure 3. Results produced by the application of TRACO to the Qualisol environment related to grain legumes *(Projets ANR LEGITIMES ET TATABOX, Ecole d'ingénieurs de PURPAN et al., 2015)*

Our knowledge in the agricultural environment allows us to go further in the analysis of the approaches to develop. One of the methods proposed by TRACO is the use of knowledge networks. Their goal is to promote learning. This aspect has been described by (Wenger, 1998). It is highly developed in agriculture within the Local Professional Groups (LPGs) (Darré, 1999). LPGs allow the grouping together of farmers who are geographically close and who have the same cultural practices. These groups can produce practical knowledge during meetings. The soil and climate variability justifies the creation of LPGs; in agro-ecology, knowledge in crop management is particularly appropriate for a given soil and climate context. The construction of local knowledge is very important. In agro-ecology, soil and climate are two very important parameters. Only LPGs can correctly build local knowledge. The joint use of farmers' meetings and "classroom" training courses is relevant, as highlighted by the

TRACO method. LPGs have tacit knowledge based on their own experience. There are two additional advantages related to the use of “classroom” training courses for LPGs. First, feedback about the same crops can be exchanged between LPGs located in different small agricultural areas ; common knowledge can be capitalised. Second, during classroom training, the animator can provide important scientific knowledge. This exchange can result in the writing of technical reports produced by both empirical and scientific knowledge. Each report constitutes a common base of knowledge that can be adapted by LPGs depending on local soil and climatic conditions.

Discussion

The study of the application in agriculture of these two tools, CKF and TRACO, allows us to define a new method for crop management:

- For a given crop, the CKF tool highlights the lack in knowledge about crop management.
- A collection of empirical knowledge from the best practitioners produces first technical report drafts.
- The “classroom” training course combines these empirical knowledge sources in order to produce more generic reports about crop management.
- Exchanges between LGP members (and with the animator) can provide technical solutions to various unsolved problems identified by CKF.
- Finally, in case of persistent lack of knowledge, more information can be provided by researchers.
- If no solution can be provided by researchers, a new research action plan must be started.

This new method must be validated in use cases.

Conclusion

Conceptual approaches - particularly the CKF method - have demonstrated that these tools can be used to integrate the spatial and temporal dimensions of agricultural production. The implementation criteria show that these tools can be used for explicit knowledge - those that people can write - and for tacit knowledge that must be transmitted by learning. These two types of knowledge are both important in agriculture. If knowledge management tools (such as the tools proposed by the French knowledge management) seem to be relevant to manage knowledge in agriculture, users need time to learn to use these tools. For some people, the use of these tools may seem a tedious and time-consuming task. To correctly analyse the survey results, it is very important to take into account the different professional categories and also the soil, climate and economic context.

In France, farming advice service is mainly provided by agricultural cooperatives and agri-business stakeholders. They provide technical recommendations (e.g. technical reports) to their members. These reports are based on the results produced by agricultural knowledge management system, but their writing is based on a top-down approach, from research results to farmers. Thanks to the tools proposed by the French knowledge management, we have developed an alternative approach. Our method involves all the stakeholder types in the agriculture (Nagel, 1979), from farmers to researchers. This approach is based on the middle-up-down knowledge management proposed in Nonaka (1994). This organisational method improves the communication between the "hierarchy" and the professional stakeholders. It facilitates the creation of tacit knowledge and their external communication, whereas the “hierarchy” tends to combine knowledge and learning.

In our opinion, methods such as proposed in this paper, are important for a sustainable agriculture that must take into account environmental impacts. Research institutes have an important role in knowledge creation. Farmers and Local Professional Groups produce tacit knowledge. The challenge is to adapt this model to middle-up-down management, a model that seems relevant to agricultural knowledge management. Agricultural cooperatives could help to structure the operational knowledge in this new paradigm of agro-ecology.

This paper presents some results produced in the TATABOX project, funded by the “Agence National de la Recherche” (AGROBIOSPHERE 2013). Its contents do not represent any official position of the National Research Agency and is fully the responsibility of the authors.

References

Club de gestion des connaissances (2004). Critical knowledge factors Critères de criticité des connaissances version 1.1. Paris: 30 pages.

Club de gestion des connaissances (2009). Guide et outil pour le choix de méthodes de transfert de connaissances. Paris.

Darré, J.-P. (1999). La production de connaissance dans les groupes locaux d'agriculteurs. L'innovation en agriculture : Questions de méthodes et terrains d'observation. IRD: Pages 93-112.

Ermine, J.L. (2008). Management et ingénierie des connaissances : Modèles et méthodes. Paris: Hermes Lavoisier.

Guichard, L., Ballot, R., Halska, J., Lambert, E., Meynard, J.M., Minette, S., Petit, M.S., Reau, R., & Soulignac, V. (2015). AgroPEPS, un outil web collaboratif de gestion des connaissances pour Produire, Echanger, Pratiquer, S'informer sur les systèmes de culture durables. Innovations Agronomiques 43: 83-94.

Magrini, M.-B., Voisin, A.-S., Anton, M., Cholez, C., Duc, G., HELLOU, G., Jeuffroy, M.-H., Meynard, J.M., Pelzer, E., & Walrand, S. (2014). La transition vers des systèmes agro-alimentaires durables : quelle place et qualification pour les légumineuses à graines ? La Grande Transformation de l'Agriculture, 20 ans après : renouveler les approches institutionnalistes sur l'agriculture et l'alimentation. Montpellier, France.

Meynard, J.M. (2012). La reconception est en marche ! Conclusion au Colloque 'Vers des systèmes de culture innovants et performants : de la théorie à la pratique pour concevoir, piloter, évaluer, conseiller et former.' Innovations Agronomiques 20: 143-153.

Nagel, U. (1979). Knowledge flows in agriculture: linking research, extension and the farmer. Zeitschrift fürAusländische Landwirtschaft 18(2): 135-150.

Nonaka, I. (1994). A dynamic theory of organisational knowledge creation. Organisation Science 5(1): 14-37.

Nonaka, I., & Toyama, R. (2003). The knowledge-creating theory revisited: knowledge creation as a synthesising process. Knowledge Management Research & Pratice (1): 2-10.

Projets ANR LEGITIMES ET TATABOX, Ecole d'ingénieurs de PURPAN et C. Qualisol (2015). Projet Légitimes.

Soulignac, V., Ermine, J.L., Paris, J.L., Devise, O., & Chanet, J.P. (2012). A knowledge management system for exchanging and creating knowledge in organic farming. EJKM / The Electronic Journal of Knowledge Management 10(2): 163-182.

Soulignac, V., Ferstler, V., Lambert, E., Dolfo, M., & Lamaze, A. (2015). 'Sillage' et 'Sillage Télédéclaration' : des logiciels pour le contrôle réglementaire des épandages de matières fertilisantes en agriculture (mai 2015). Techniques, Sciences, Methodes (7-8): 52-62.

Wenger, E. (1998). Communities of practice : learning, meaning and identity New York, Cambridge: Cambridge University Press.

Dissemination and implementation of agricultural innovations using video on mobile phones in Mali

Sousa, F., Nicolay, G. and Home, R.

FiBL – Research Institute of Organic Agriculture, Switzerland

Abstract: A challenge for researchers and other developers of new technologies in agriculture is to find ways of communicating their results and recommendations. This challenge is particularly acute in regions in which farmers have limited access to education and where illiteracy is widespread, such as in the rural areas of Mali. One approach that shows potential, yet remains largely unused by extension services, is the dissemination of educational video on mobile phones with video and Bluetooth technology, which are widespread in the region. This article aims to explore the potential of video on mobile phones as a tool for farmer-to-farmer exchange and agricultural extension in Western Africa. Three videos showing agricultural innovations were shown and shared with 200 farmers in twelve villages in Mali. The villages were revisited 10 months later and farmers were asked about their experiences with the videos that had been shared and their previous knowledge of the innovations shown in them. It was found that participating farmers had shared the videos on their phones with an average of 5.9 other farmers, and had shown the videos to an average of 9.9 other farmers. Of the farmers who had watched one of the videos (N=148), 60.1% had adopted at least one of the videos' innovations. Mobile phone videos could be accessed by people who have previously received limited access to information sources, such as younger women, and video based information was found to be understandable for illiterate farmers. These results allow the conclusion that using video based information transfer can enhance information transfer and thereby expand its outreach. The use of video on mobile phones is a novel approach to farmer-to-farmer exchange and has tremendous potential for enhancing dissemination programs or specific research and development projects to enable more resilient, inclusive and democratic systems.

Key words: Information and communication technology, mobile phone, video, agriculture development, rural extension, farmer-to-farmer exchange, Africa

Introduction

Developers of agricultural innovations typically find that adoption of their new technologies tends to be quite low (Aguilar-Gallegosa et al, 2015), although Kiptot et al. (2007) found that the process of adoption of new technologies is highly dynamic and variable. The technology acceptance model (TAM) (Davis, 1989) suggests that new technologies will be adopted if they are perceived to be both useful and usable. The TAM was formulated to explain technology adoption across a broad range of innovation types, but it has not yet been investigated whether the model is applicable to the adoption of agricultural innovations: in other words whether agricultural innovations can be considered to be new technologies. Researchers in the field of agriculture must be in tune with the needs and demands of farmers, and convince them of tangible benefits, if they wish to see their research findings widely adopted (Kiptot et al., 2007). The implication of this is that there are two steps in the process of encouraging adoption of innovations. Firstly the innovations themselves must be perceived to be useful and usable in the intended context. Secondly, their use and usability must be communicated in a way that is understandable in the specific context so that it is able to convince the farmers of the benefits.

The aims of this contribution are to identify the conditions that enable adoption of agricultural innovations and to investigate whether the TAM can be applied to encourage adoption of innovations. Given that application of the TAM is context specific, we address these aims in the context of rural Mali in western Africa. We first examine existing literature to find a context-appropriate means of information transfer. Once an appropriate means of information transfer are identified, we determine whether innovations are actually implemented after they have been communicated. The logic follows the argument that, if innovations have been implemented, both the first condition: that the farmers perceived them to be useful and usable; and the second condition: that the farmers have learned of the innovations, must both have been met. In other words, implementation of innovations, in this case, provides experimental support for the TAM in predicting adoption of rural innovation.

Appropriate means of information transfer

Aguilar-Gallegosa et al. (2015) point out that diversified, and tailor-made, extension strategies should be designed for the conditions of specific target groups. Radio and television programmes, which have usually been approached from the top-down and organised by structured extension services, have historically formed the bulk of information and communication technology (ICT) for agricultural extension in Mali (Bentley et al., 2014). However, social networks play an important role in the creation, as well as in the adoption, of innovation in agricultural contexts, with farm managers learning in informal processes within networks of colleagues and advisers (Gielen et al., 2003). This suggests that information transfer between peers, in this case between farmers, may be an effective approach to knowledge creation and/or dissemination. Furthermore, subsistence farmers in Mali may face special challenges in the organisation, storage, and communication of the created knowledge, which suggests the value of user operated ICT systems to support the farmers.

Methods for transferring information to farmers have been the focus of research for some time, but methods have to be suitable for the target groups (Aguilar-Gallegosa et al., 2015), which suggests that methods can't just be copied from other places without consideration of context. Ramkumar (2007) implemented a farmer-usable touch screen information kiosk in a veterinary institution, which helped cattle owners to treat their animals at an early stage of a disease. Farmers in the UK were found to be informed by a relatively stable network of other communities of practice (or networks of practice), which Oreszczyn et al. (2010) called a 'web of influencers on practice'. However these techniques may not be suitable in environments such as rural Mali, which have neither a developed web of influencers nor an institution that could host an information kiosk. Sulaiman et al. (2012) argue that acknowledgement and integration of intermediaries, and their capacities for innovation, could enhance the potential of ICTs by ensuring that the information is provided in ways that enable communities to make use of it. Effective use of ICT must be appropriate to rural realities, which, in much of rural Africa, is within the context of widespread illiteracy and sometimes limited, or even non-existent, extension services (Aker, 2011; Cole & Nilesh, 2012; Gurumurthy, 2006; Zossou et al., 2010).

A number of projects using ICT have taken place in different rural areas around the globe to enable top down communication of content. Digital Green in India produces videos and provides public screenings in villages to transfer information and enable exchange on best agricultural practices that can boost farm productivity and improve nutrition (Ghandi, 2007). The African Cashew Initiative provided an ICT-based pricing and weighing system that can be used by farmers during the marketing season, with farmers being updated directly via their mobile phones (Kachelriess-Mathess et al., 2013). The Lifelong Learning for Farmers programme in Uganda provides an interactive SMS service with relevant agricultural information for farmers (SIANI, 2012). Mobile phones have been successfully used in Niger to communicate prices of agricultural products directly to farmers (Aker, 2008). The iCow initiative in Kenya is a centralised cattle management system which has adopted the use of text messages and video (Kahumbu, 2012).

Videos on mobile phones have been effectively used to spread information on cowpea hermetic storage practices and other agricultural innovations (Baributsa et al., 2010). Cai and Abbott (2013) demonstrated that agricultural extension strategies can be complemented by the use of video in farmer training and that it can help overcome the gender barriers in information access. A successful application of ICT was achieved by Van Mele et al. (2010), who found that open-air video presentations facilitated unsupervised learning; unleashed local creativity and experimentation; and built confidence, trust, and group cohesion among rural people, including the poor, youth, and women. Although the use of video appears to be a promising means of information transfer, Sulaiman et al. (2012) argued that ICT based initiatives will be enhanced if they are embedded in a pragmatic world of communication and innovation process, which could be achieved when the power of distribution and intermediation of ICT content lies with farmers. One way of placing control of content and distribution in the hands of farmers is to use ICT systems that farmers already own. Bentley et al., (2014) cite farmers and local extension workers in Mali as having noted the promising potential of video on mobile phone and Bluetooth technology but that these technologies remain essentially unused in agricultural extension in Mali.

In recent years, third generation mobile phones (3rd MP), with video and Bluetooth capability, have become an important tool for communication in rural Africa (Asenso-Okyere & Mekonnen, 2012; Simba, 2014; Mwombe et al., 2013). Rural Africa has experienced a particularly high uptake of information and communication technology (ICT) in the last 3 to 4 years (Jere & Erastus, 2015). Lawal-Adebowale (2012) argues that mobile-phones are the most widely used ICT device in Western African rural areas, with 62.9% of farmers in rural Nigeria owning such a device. Sousa et al. (under revision) found that 92.5% of their sample of 400 farmers in Mali had a family member who owned a Bluetooth capable phone and all knew someone who possessed one, so had at least indirect access to 3rd MP technology. Furthermore, Sousa et al. (under revision) found that Malians watch videos on mobile phones; mostly in groups and very frequently in the public places of the village. These findings underline the potential of video use in 3rd MP as a component of an agricultural extension strategy.

While this review of relevant literature was able to identify the potential of 3rd MP as a means of information transfer in Mali and Burkina Faso, there is little reported evidence of a connection between information transfer and the implementation of innovation. Primary data is needed to determine whether the conditions for adoption of innovations have been met and whether the TAM provides a useful framework for understanding the conditions.

Methods

Several videos were produced in 2013 as part of Syprobio's project dissemination strategy. Syprobio (Systèmes de Production Biologiques) (Nicolay, 2013)[1] was a EuropeAid funded project running from 2011 to 2015 that aimed at promoting farmer lead innovation in an organic farming context in Burkina Faso, Mali, and Benin. These videos were produced in a format that was easily comprehensible to farmers to portray different innovations that had been tested in Mali and neighbouring Burkina Faso. Three of these videos were selected after pilot interviews had identified topics that were of interest to farmers in the Bla area of Mali. One video described the production and use of a bio-pesticide using Neem and hot pepper. A second video compared three different ways of applying compost: uniformly, in rows, and in pockets. A third video showed different crop associations. The three videos were shown and shared with 200 farmers using Bluetooth technology, at no cost to the farmers, in September/October 2013. None of the 200 farmers were informed that there would be a second round of interviews after the initial contact. The same team returned to the area in July/August 2014, and were able to find and interview 95 of the 200 farmers with whom the videos had been shared ten months earlier. This sample was supplemented by a further 84 farmers with whom the video had not been shared in the initial introduction of the videos. The final sample size was 179 farmers.

The theoretical framework used in this analysis is the technology acceptance model (TAM) (Davis, 1989), with the extension applied by Sousa et al. (under revision) to include control beliefs. The extended TAM suggests that new technologies will be adopted if they are perceived to be useful, perceived to be usable, and that the technology is available. Given the widespread availability of 3rd MP, and the access to people with the technical skills to use them, this suggests that the videos will be shared if they are perceived to be useful. A second level, in this case, is whether technologies portrayed in videos will be adopted, and the same theoretical framework can be applied. The theory suggests that if the innovations are perceived to be useful and are perceived to be easy to use, they will be adopted. These theoretical considerations are expressed in practical terms as whether people have implemented the innovations contained in the videos.

Results and Discussion

How 3rd MP videos were shared and how they spread

From the farmers who received the videos in their mobile phone in September and October of 2013 (N=95), 73 shared the video via Bluetooth with other farmers (76.8%) and 22 did not (23.2%). The main reasons stated by those who did not share the video were: "lost the video before able to share" (9, N=22); "other people already had the video" (5, N=22); "other people saw it, but didn't ask for it" (7, N=22); and "no knowledge of Bluetooth" (1, N=22).

Those who did share the video via Bluetooth (N=73), shared it with a total of 431 farmers, to give an average share rate of 5.9 people per farmer. This rate is similar to that found by

[1] *www.syprobio.net*

Baributsa et al. (2010) in a study of farmers in Niger and their sharing of a cowpea storage video. It is impossible to track how many shares happened in second degree but if we assume a slightly lower share rate of 5 shares per farmer, the number of second-degree video users would rise to 2155. If we go further and assume a third degree share with the same rate, the number would be 10775, from the initial 73 farmers (Figure 1). These are however projections and it is impossible to know the real number of farmers who have the video on their 3rd MP. Population density and mobile phone penetration are probably the factors that will most influence the real numbers.

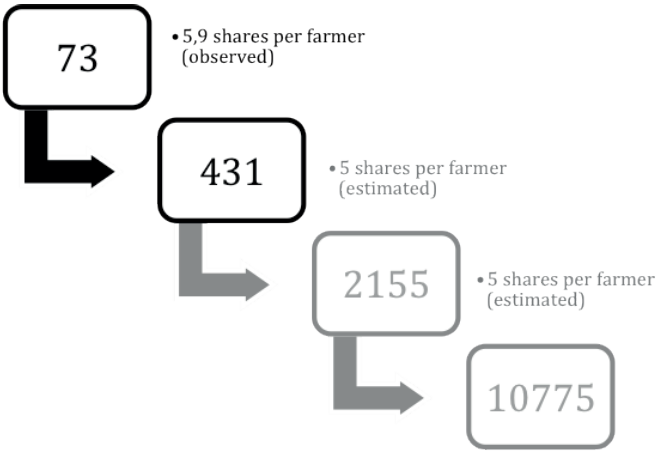

Figure 1. Video shares via Bluetooth: observed values (black) and estimated (grey).

Video transfer via Bluetooth is not the only way of describing the information flow, since videos are also visually shared with those who do not own a 3rdMP. Farmers who received the video showed it to 9.9 other people on average, which is a higher number than the average share rate of video via Bluetooth. This result has implications for the real number of people who had access to the information. From the sample with whom the videos were not shared in 2013 (N=84), 53 (63.1%) had been shown the videos by other farmers. Our data supports the notion that the Bluetooth and visual sharing of videos by farmers can scale-up information in a self-propagative way; not only within villages but also to people outside them.

The videos spread to other villages and towns according to the movements of farmers who initially received the video, as well as through contacts with visiting farmers from other places. The 73 farmers who received the videos said they transferred them via Bluetooth to farmers from 34 new villages. This brings the total of villages in which the videos were present from 12 to 46 in 10 months. On average, each farmer (N=73) transferred the video to farmers from 1.99 villages, with a minimum of 1 and a maximum of 6. Most of the new villages to which the videos were spread were located within 50 km of the centre of the study area (Figure 2).

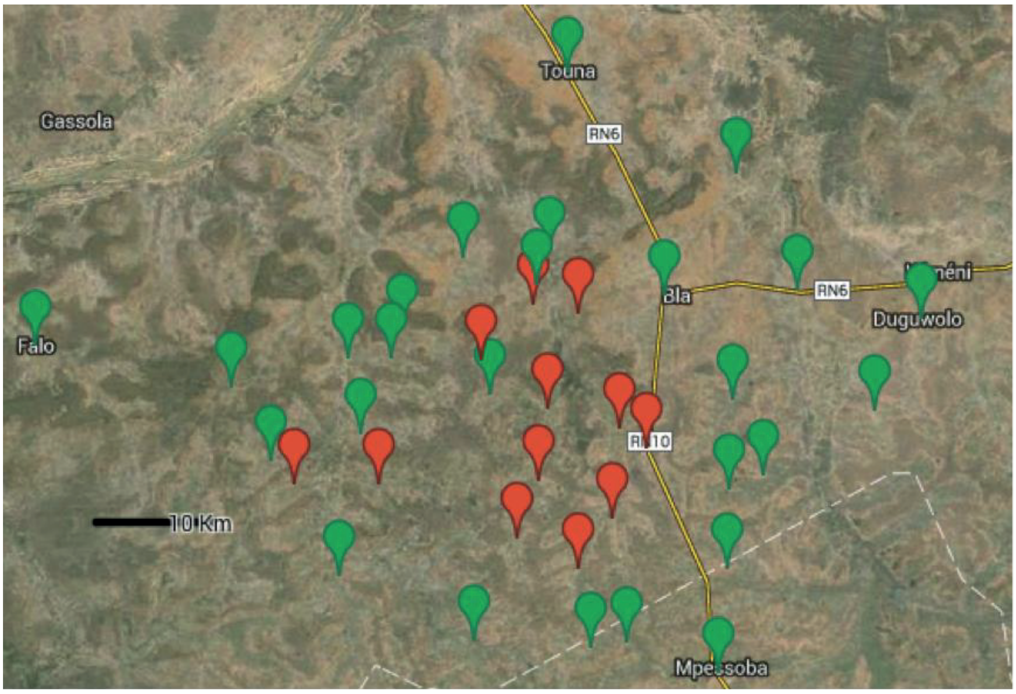

Figure 2. In red, the villages where the videos were initially shared in 2013; in green, the villages where videos had been transferred via Bluetooth after 10 months.

The video transfer flowed more frequently to neighbouring villages, where contact with friends and family is more regular and likely. However, internal temporary migrations and other types of travel (family visits, ceremonies, trainings etc.), mean that some transfers occurred outside the 50 km range. Video presence was recorded in Kolokani (in the region of Bamako, 250 km northeast); Bledioni (in the region of Sikasso, 120 km south); Markala (in the region of Segou, 90 km north); and Tominian (in the area of San, 145 km east). It is impossible to know the full extent to which the videos were shared in Mali. Some farmers with whom the videos had been shared in 2013 were not present in their villages at the time of the last fieldwork. Furthermore, we don't know the extent to which second and third degree transfers took place.

Rate of video innovation adoption

A further means of evaluating the reach and usefulness of the videos was to assess whether the videos had enabled innovations to be implemented. Farmers were considered to have adopted an innovation (enabled by the videos) if it was specifically stated that it was the first time they had applied the technique and that the video was the information source. An exception is the case of crop associations, which is an old practice that has fallen out of use. Farmers were considered to have adopted this innovation (enabled by the videos) when they stated having been explicitly motivated by the video to apply this technique.

Of the farmers who had watched the videos (N=148), 89 (60.1%) had applied at least one of the videos' innovations; 46 (31.1%) had not applied any of the innovations; and 13 (8.8%) of the farmers either didn't know or didn't answer. The innovation with the highest implementation rate was the 'compost application technique', which was implemented by 74 of the 89 (83.1%) farmers. Despite the video referring to cotton, many farmers applied this technique to other crops, such as maize, sorghum, millet, okra and watermelon. The higher rate of implementation seems to be related mainly to the perception by farmers that compost is a scarce resource and must be maximised to improve productivity. For the farmers who adopted the innovation, it was important to see the results in the video and to hear the testimonies of farmers talking about their results. Many applied the compost in pockets or in lines, as was suggested in the video. The farmers reported that their main limitation was the availability of workers. All of the farmers who had implemented the innovation had previously applied compost in a uniform way in their fields before watching the video.

The ‘crop associations’ innovation was applied by 14 (15.7%) farmers. The most commonly used varieties were maize, sorghum and cowpeas, which were the crops shown in the video. Some farmers included sesame and cotton in the mix. Two farmers applied both compost application techniques and crop associations. The third video provided information about a biopesticide using *Cassia nigricans* and hot pepper, which had been tested in Burkina Faso. This innovation was hardly applied since *Cassia nigricans* is not used in the area, and the most widely used biopesticide is based on neem seeds. The implementation rate of the three videos is summarised in Table 1.

Table 1. Summary table describing innovation implementation rates

Innovation	N	%	Observations
Compost application techniques	74	83.1	Farmers applied compost in pocket or in line instead of uniform as they used to.
Crop associations	14	15.7	Farmers restarted mixing crops or did it for the first time with the mix suggested in the video.
Biopesticide (*Cassia*+pepper)	1	1.1	*Cassia* is unknown in the area.
Total	89	100	

Conclusions

As demonstrated by Sousa et al. (under revision), farmers in the rural areas of Mali have generalised access to third generation mobile phones (3rdMP), as well as the skills to use it, and to perceive its potential use as an agricultural information tool to be beneficial to them. The technology acceptance model (Davis, 1989) requires that these three conditions be met in order to consider a technology as having potential to be adopted. In the light of this explanatory framework, the results of this study support 3rdMP as having a strong potential as a means of farmer-to-farmer information transfer, since it was widely used by farmers to share the innovations portrayed in the videos, with some being implemented in their fields. The results of this study reinforce the proposal that videos can play an important role in enabling farmers to implement innovative practices. This finding is in line with Ghandi et al. (2007), who showed that video based diffusion strategies can increase the adoption rates of agricultural practices by a factor of six to seven times the classical person-only agricultural extension. Similarly, Zossou et al. (2010) found that a video on rice parboiling in rural Benin reached three times more women than did training workshops that had been organised by local NGOs.

The use of videos was shown to create a horizontal platform of information exchange among the rural population, relying on farmers’ own personal contacts and being independent from the typically top-down information transfer from extension structures (Vanclay et al., 1994) or pure video or radio transmissions (Okry et al., 2013; Van Mele et al., 2013). The participatory production of videos for mobile phones; involving farmers and their own messages, further enhances the dissemination and implementation of innovations because of the trust among peers, who share similar circumstances and problems and the same vernacular language.

Widespread illiteracy is recognised as a major constraint in the process of dissemination and implementation of agricultural innovations in most of Western Africa's rural areas (Aker, 2011). Videos on mobile phones provide an opportunity to overcome this obstacle, allowing the production of messages that can be easily understood by farmers and easily translated to local vernacular languages. This type of information exchange can greatly amplify agricultural extension efforts and prevent the exclusion of specific groups, such as women and younger farmers. Furthermore, the self-propagative characteristics of this technology could lower extension efforts while increasing the rates of dissemination and adoption of agricultural innovations.

The implementation of the compost application technique in rows, as opposed to uniformly, was by far the most popular innovation; answering to some of the farmers' main concerns such as crop productivity and low soil fertility. The crosscutting characteristics of this information transfer provided that the technique was implemented not only with cotton, as portrayed in the video, but also in other crops grown by farmers. This flexibility in the implementation of the acquired knowledge implies that more democratic information transfer tools can have a deep impact in a rural society that is eager to access new agriculture related information; further adapting it to its needs. This communication strategy ultimately enables, in an unprecedented way, farmers to become the owners of relevant and easily shareable information, which can then be adapted to their needs. We conclude that a communication strategy involving videos on mobile phones has tremendous potential to be effective and may increase the rates of dissemination and implementation of agricultural innovations, particularly in the rural areas of the developing world.

Acknowledgements
This study was conducted in the area of Bla, Mali. We would like to thank UNPCB, MOBIOM, CRRA-IER and INERA. Special thanks go to the following members of the Syprobio project team: Rémy Dabire, Laurent Glin, Fagaye Sissoko, Kouka Yameogo, Odiaba Samake, Andreas Fliessbach, Karim Coulibaly and Daouda Konaté. We are especially grateful to all farmers involved in the study in Mali and Burkina Faso who gave their time freely.

References

Aguilar-Gallegos, N., Muñoz-Rodríguez, M., Santoyo-Cortés, H., Aguilar-Ávila, J., & Klerkx, L., (2015). Information networks that generate economic value: a study on clusters of adopters of new or improved technologies and practices among oil palm growers in Mexico. Agricultural Systems 135: 122-132.

Aker, J. (2008). Does digital divide or provide? The impact of cell phones on grain markets in Niger. Centre for Global Development, Working Paper 154.

Aker, J. (2011). Dial "A" for agriculture: a review of information and communication technologies for agricultural extension in developing countries. Centre for Global Development, Working Paper 269.

Asenso-Okyere, K., & Mekonnen, D. (2012). The importance of ICTs in the provision of information for improving agricultural productivity and rural incomes in Africa. Working Paper. UNDP Regional Bureau for Africa.

Baributsa, D., Lowenberg-DeBoer, J., & Kamarou Djibo, A. (2010). Cell phone video for communicating hermetic cowpea storage skills. 5th World Cowpea Conference, Senegal.

Bentley, J., Van Mele, P., Zoundji, G., & Guindo, S. (2014). Social innovations triggered by videos: Evidence from Mali. Ghent, Belgium: Agro-Insight Publications.

Cai, T., & Abbott, E. (2013). Using video as a replacement or complement for the traditional lecture/ demonstration method in agricultural training in rural Uganda. Journal of Applied Communications 97(4): 47-61.

Cole, S. & Nilesh, F. (2012). The value of advice: evidence from mobile phone based agricultural extension. Harvard Business School Working Paper no.13-047.

Davis, F.D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Quarterly 13(3): 319-339.

Jere, N., & Erastus, L. (2015). An analysis of current ICT trends for sustainable strategic plan for southern Africa. Proceedings of IST-Africa 2015 Conference.

Gielen, P.M., Hoeve, A., & Nieuwenhuis, L.F.M. (2003). Learning entrepreneurs: learning and innovation in small companies. European Educational Research Journal 2: 90-106.

Gurumurthy, A. (2006). Promoting gender equality? Some development-related uses of ICTs by women. Development in Practice 16(6): 611-616.

Kahumbu, S. (2012). Cows in the cloud: Kenyans are registering their cows, and increasing their milk yields, on their mobile phones. http://www.ilri.org/ilrinews/index.php/archives/10173

Kiptot, E., Hebinck, P., Franzel, S., & Richards, P. (2007). Adopters, testers or pseudo-adopters? Dynamics of the use of improved tree fallows by farmers in western Kenya. Agricultural Systems 94: 509-519.

Lawal-Adebowale, O.A. (2012). ICT in agricultural development: its diffusion and adoption pattern in Nigeria's agricultural system. In B. Maumbe and C. Patrikakis E-Agriculture and Rural Development: Global Innovations and Future Prospects. USA: IGI Global.

Mwombe, S.O.L., et al. (2013). Evaluation of information and communication technology utilisation by small holder banana farmers in Gatanga District, Kenya. The Journal of Agricultural Education and Extension 20(2): 247-261.

Okry, F., et al. (2013). Forging new partnerships: lessons from the dissemination of agricultural training videos in Benin. The Journal of Agricultural Education and Extension 20(1): 27-47.

Oreszczyn, S., Lane, A., & Carr, S. (2010). The role of networks of practice and webs of influencers on farmers' engagement with and learning about agricultural innovations. Journal of Rural Studies 26: 404-417.

Ramkumar, S., Garforth, C., Rao, S.V.N., & Heffernan, C. (2007). Design and formative evaluation of an information kiosk on cattle health for landless cattle owners. The Journal of Agricultural Education and Extension 13: 7-22.

SIANI (Swedish International Agricultural Network Initiative) (2012). From motorbike to mobile phone: new extension services for rural farmers through mobile ICT. Discussion brief. Stockholm, Sweden.

Simba, F.Y., & Zaipuna, O. (2014). ICT as a tool for improving information flow among livestock stakeholders. A case study of Tanzania. International Journal of Computer Science and Information Security 12(8): 414-424.

Sousa, F., Nicolay, G., & Home, R. (Under revision). International Journal of Agricultural Sustainability.

Sulaiman (R), V., Hall, A., Kalaivani, N.J., Dorai, K., & Reddy, T.S.V. (2012). Necessary, but not sufficient: critiquing the role of information and communication technology in putting knowledge into use. The Journal of Agricultural Education and Extension 18: 331-346.

Vanclay, F., & Lawrence, G. (1994). Farmer rationality and the adoption of environmentally sound practices; a critique of the assumptions of traditional agricultural extension. European Journal of Agricultural Extension and Education 1(1): 59-90.

Van Mele, P., Wanvoeke, J., & Zossou, E. (2010). Enhancing rural learning, linkages, and institutions: the rice videos in Africa. Development in Practice 20: 414-421.

Van Mele, P. (2013). Video-Mediated Farmer-to-Farmer Learning for Sustainable Agriculture. Ghent, Belgium: Agro-Insight Publications.

Zossou, E., Van Mele, P., Vodouhe, S., & Wanvoeke, J. (2010). Women groups formed in response to public video screenings on rice processing in Benin. International Journal of Agricultural Sustainability 8(4): 270-277.

From citizens' to farmers' science: are smartphone technologies a useful tool in participatory agricultural research?

Dehnen-Schmutz, K., Foster, G., Owen, L. and Persello, S.

Centre for Agroecology, Water and Resilience, Coventry University, UK

Abstract: Over the last decade citizen science approaches have become increasingly popular in several disciplines supported by the proliferation of mobile communication technologies such as smartphones. However, citizen science methodologies involving large numbers of participants seem not to have been widely adopted in agricultural research, even though participatory on-farm approaches involving small farmer groups are now more widely used. Here, we present results of an online survey amongst British and French farmers, investigating i) smartphone use in various farm management practices, and ii) the interest of farmers to participate in citizen science projects. Eighty-nine percent of the 57 respondents from Britain and France owned a smartphone, which was also the device they used most often on a daily basis for farm management when compared to other communication devices (including laptop and desktop computers, tablets and landline telephones). A third of farmers using their smartphone for farm management were not using any farm management specific applications on their smartphone, but of the farmers that did, an average of four applications were used. Farmers were very positive about citizen science regarding it as a useful tool for data collection, real-time monitoring, identification of research questions, experimental work and wildlife recording on farm. They showed strong interest in participation in citizen science projects with varying and often high time commitments. Experimental work was the most likely activity for which respondents felt some financial support was necessary. This paper is the first to quantify and explore farmers' use of smartphones for farm management in Europe, and to document farmers' support and potential interest to participate in farm related citizen science projects. Smartphone technologies offer great potential for participatory agricultural research, and our results show that farmers tend to have sufficient knowledge of the technology as well the enthusiasm to engage in citizen science. This paper provides a basis and justification for the wider application of smartphone technologies in future participatory research projects that are concerned with exploring pathways towards greater agricultural sustainability and resilience.

Keywords: Citizen science, smartphones, farm management applications, Britain, France, participatory research