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MOTIVATIONS AND NEEDS FOR ADOPTION OF THE AGRICULTURAL DECISION SUPPORT SYSTEM CropSAT IN ADVISORY SERVICES

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A B S T R A C T

This paper presents several strategies employed by advisors in relation to the use of a Swedish agricultural decision support system (AgriDSS) called CropSAT, which is free to use and funded by the Swedish Board of Agriculture. The research questions for the study were: How is extension affected and possibly altered when provided with CropSAT? 2) How can advisory strategies in relation to PA technology use be categorised? Fourteen crop production advisors were interviewed, and the collected data were analysed thematically. The findings revealed four different extension strategies in relation to CropSAT use: 1) I do not use it, 2) I use it if I have to, 3) I use it myself and tell the farmer how to fertilise, and 4) I use it with the farmer. The obtained results indicate that the strategies selected by the advisors varied based on the requests and needs of farmers, the advisors' personal interests and competences, CropSAT functionality, and uncertainty about how to use it in practice. When using an AgriDSS such as CropSAT in advisory situations, the complexity increases because there are more parameters to consider, and thus it could be experienced as more difficult to make proper decisions. As a result of the combination of technology and agronomy, the advisors requested more support. We argue that this request must be met by research, the authorities and the companies responsible for developing the AgriDSS. We claim that in order to increase the use of AgriDSS to optimise crop treatment at the right time and on the smallest possible scale, there is a need for a change in mind-set by among both advisors and farmers in order to increase sustainability in agriculture.

Keywords: Precision agriculture, advisor, fertilisation, crop production, agricultural decision support systems (AgriDSS), situated seeing.

INTRODUCTION

In Agriculture is facing huge challenges given the requirement for what is known as sustainable intensification (Garnett *et al*., 2013) to bring about a *"more than doubling of the agri-food production while at the same time at least halving our ecological footprint"* (Sundmaeker *et al.,* 2016). In a sustainable intensification trajectory, the aim is to increase food production on existing farmland and decrease the environmental impacts, using context-dependent strategies that take both social and natural scientific knowledge into consideration (Garnett *et al*., 2013). In such a trajectory, different stakeholders, including individual farmers, will need to develop situated knowledge that is complex, diverse and local (Leeuwis, 2004). In order to handle an increase in complexity in large-scale farming systems at least, information and communications technology (ICT) and other technologies have an important role to play (Aubert, Schroeder & Grimaudo, 2012). Various kinds of ICT systems and concepts, such as smart farming and Precision Agriculture (PA), are expected to be important tools in dealing with this complexity (Sundmaeker *et al.,* 2016; Wolfert *et al.* 2017). PA is a management concept that is based on observing, measuring and responding to within-field variations, providing farmers with opportunities to recognise and handle within-field variations to a much greater extent than ever before (Aubert *et al.,* 2012; Wolfert *et al.,* 2017).

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In order to perform PA, certain kinds of ICT systems, known as agricultural decision support systems (AgriDSS), have been developed. An AgriDSS must fit with the farmers' practice and be combined with farmers' situated knowledge and experience in order to function properly (Nitsch 1994; Lundström & Lindblom, 2016; 2018). Instead of considering an AgriDSS as a strict operational tool, to help farmers make decisions, many researchers highlight the possibility of using an AgriDSS for social learning, that can facilitate discussions and learning among different stakeholders (e.g. Evans *et al.,* 2017; Hochman & Carberry, 2011; Jakku & Thorburn, 2010; Lundström & Lindblom, 2016; 2018; Matthews *et al.,* 2008; McCown *et al.,* 2009; Thornburn *et al.,* 2011). When an AgriDSS is used as a learning tool, it could frame a change from goal-orientated thinking towards thinking in terms of learning (Schlindwein *et al*., 2015). To facilitate such learning processes, advisors play a central role.

In previous work, we studied farmers' socio-technical systems through qualitative inquiry, investigating the use of a Swedish AgriDSS called CropSAT by four farmers and their advisors in relation to making decisions about the Nitrogen (N) fertilisation of winter wheat (for further details see Lundström & Lindblom, 2016; 2018). The study revealed that CropSAT can provide new information about a field and facilitate action, learning and decision-making when considering fertilisation (Lundström & Lindblom, 2016; 2018). Hence, CropSAT provided new kinds of digital representation formats that visualised the within-field variation in biomass with more clarity than can be achieved with the human eye alone, as well as a possibility of applying N fertiliser adapted to this recognised variation. The major challenge identified was how to deal with biomass variability by setting the five levels of N fertilization in CropSAT. In this cognitively demanding process, social interactions with a willing and able advisor, reflecting on field observations as well as different representations such as soil maps and other measurements from the field, were valuable and functioned as coordinating mechanisms. Thus, the advisor had an important role to play in the adoption and use of CropSAT by supporting technology use for both learning and decision-making (for further details, see Lundström & Lindblom, 2016; 2018).

The present study was conducted during 2016-2017, in which fourteen additional advisors from other parts of Sweden were interviewed to complement the earlier findings (Lundström & Lindblom, 2016; 2018). The aim of this paper is to investigate and analyse extension strategies in advisory situations, based on access to and use of CropSAT (www.cropsat.se). The research questions were: 1) How is extension affected and possibly altered when provided with the new AgriDSS CropSAT? 2) How can advisory strategies in relation to PA technology use be categorised? Based on the results obtained, we also discuss the preconditions that make an AgriDSS credible and usable for advisors in practice when planning and discussing fertilisation with farmers.

Theoretical background: In Sweden, for many years there has been considerable debate about fertilisation in order to optimise crop yield and avoid environmental impacts. The Swedish Board of Agriculture publishes N recommendations for crop production on a yearly basis (Albertsson *et al.,* 2016). Based on these recommendations decision-makers should take a great many parameters into account and adapt the amount of N to crop yield, but still consider an average yield for each field. Although farmers, for many years have been encouraged and advised to take soil samples, and even if most farmers know from experience that the yield could vary considerably within a field, the tradition of adaptation to crop need without considering within-field variation does not seem to be a common consideration. However, over the last couple of years there appears to be increasing complexity in the N fertilisation of wheat and malting barley. Some of the underlying reasons for this way of acting can be summarised as large differences in weather conditions, new varieties that have considerably higher N optimums under good conditions, discussions about stagnating yields, reasonable prices and common access to the AgriDSS CropSAT that visualises within-field variation via an open-access website funded by the Swedish Board of Agriculture. In 2015, there were high yields and low protein content in winter wheat and malting barley (http://www.sverigeforsoken.se/se/sok.asp) and therefore many farmer' suffered economic losses, which in turn increased the interest in precision fertilisation and the use of PA AgriDSS. Thus, increased complexity creates a demand for new interventions, which turn us to the next topic, AgriDSS.

ICT systems that support users with decision-making are called decision support systems (DSS) (Alenljung, 2008). The aim of DSS is to reduce the effects of weaknesses in human decision-making or cognitive limitations by increasing the user's ability to process huge amounts of information or by expanding the perception or imagination of the decision-maker. DSS can support decision-makers in making more effective decisions when dealing with unstructured or semi-structured problems, which are often ill-defined and complex and without clear and obvious solutions. By definition, DSS are not intended to replace decision-makers, but rather to support them in the decision-making process. They are interactive, which implies that there is an exchange between the system and the user. Decision-makers must be able to identify a change in the conditions, which is why DSS must be adaptive and flexible to meet user needs and allow modification by the user (e.g. Alenljung, 2008; Power, 2002; Turban *et al.,* 2007). To date, agricultural researchers have had the intention of using AgriDSS to transfer knowledge from science to practice, with the aim of increasing farmers' acquisition of scientific knowledge (e.g. Evans *et al.,* 2017; Leeuwis, 2004; McCown *et al*., 2009; Thornburn *et al*., 2011). However, if the AgriDSS will be used, it must be credible and fit well into the decision-making milieu of the user (e.g. Matthews *et al.,* 2008). Consequently, it is important to acquire a better understanding of how individuals in complex situations actually make decisions and use AgriDSS for social learning, taking into consideration the whole complex socio-technical context in which extension has an important role to play. Moving towards increased sustainability in agriculture, one important lesson learned is that there is no *"generally applicable agricultural development model"* (Leeuwis, 2004). Rather we need knowledge that is complex, diverse, local and probably developed in close cooperation between different stakeholders (Leeuwis, 2004). Thus, the traditional knowledge transfer model for extension, with an expert sending a message, an intermediary and a receiver, is no longer a useful model. Extension is about communication, with people exchanging meanings with the aim of reaching cognitive change and changes in action (Leeuwis, 2004). The knowledge needed to deal with complex situations is diverse and thus different people with different skills and expertise are required as well as technology. An AgriDSS can supplement and facilitate farm management, i.e. technology is essential for handling large data samples, measuring properties that cannot be detected by the human vision system, and providing valuable, credible representations of complex situations that clarify and support actions without losing the complexity. Consequently, they support, but do not replace decision-makers (Lindblom *et al.,* 2017). The adoption of new technology or knowledge is a learning process that involves 1) the collection, integration and evaluation of new information and 2) the adaptation of the innovation to the user's situation (Pannel *et al.,* 2006). Thus, relevant knowledge must be provided both from the inside (probably the farmer) and the outside (possibly an advisor), and it is more likely that the inside knowledge will be the dominant force in an innovation process (Leeuwis, 2004). An experienced farmer could be considered an expert on his or her farm due to the development of a considerable amount of situated knowledge (Hoffmann *et al.,* 2007), which in turn is necessary for the coordination ability of farmers when applying *"complexities of farming on a specific farm"* (Nitsch, 1994).

Thus, we should not consider the advisor as an expert and the farmer as a passive receiver, but rather that both are individuals with different but complementary knowledge that is required in order to drive the learning process forward. When using an AgriDSS as CropSAT for decision-making and learning, the user needs to combine the visualisation of the crop by satellite images with, for instance, other digital representations, previous experience or situated knowledge as well as field observations. Consequently, a significant role for the advisor is to support the adaptation of new technology into farming practice. In so doing, the advisor should facilitate farmers in combining their situated knowledge with the digital representations of the field, thus supporting their development of their so-called enhanced professional vision (see Lundström & Lindblom, 2016; 2018), with the aim of achieving fertilisation interventions that are closer to the optimum. In the case of N fertilisation, this is a process that presents new prerequisites each and every year.

The users of an AgriDSS need to develop new strategies or a situated seeing (Hutchins, 1995; Lundström & Lindblom, 2018), i.e. their cognitive strategy to accurately use the digital artefact in the existing practice to enhance farmers professional vision and develop their situated knowledge. Situated seeing can be characterised as ways of seeing the world where internal structures (individual experience and knowledge) are placed on top of available external structures (AgriDSS, the field, maps etc.) in order to construct an understanding of the task at hand in a certain situation (Hutchins, 1995). In order to accomplish situated seeing, the use of external devices, e.g. physical artefacts, plays an important role for the way in which cognition and learning can be performed by manipulating these physical devices. In this particular situation, the advisor need situated seeing for using and interpreting the digital representations of the within-field variations in biomass in an AgriDSS like CropSAT, combined with prior situated and embodied knowledge, maybe first-hand experiences by walking in the fields and finally probably in interactions with a farmer. Hence, the development of situated seeing is considered as a learning process where the individual's learning ambitions or interests are crucial for the result.

Rogers's (1995) diffusion of innovation theory defines the innovation process as *"a process by which an innovation is communicated by a communication channel over time to members of a social system".* Individuals are characterised in four groups due to their interest in innovation adoption: innovators, early adopters, late adopters and laggards. In the process, change agents have a central role to facilitate the innovation process and in agriculture, advisors are viewed as central change agents due to their role in the agricultural knowledge and innovation system (AKIS). When stimulating better management practices, farmers' can either be more or less pro-active or re-active in their relationship with advisors, and the relationship can be steered by either the advisor, or the farmer, or it can be more equal (Ingram, 2008).

The combination of experienced farmers' knowledge and advisors' knowledge would probably have the best/optimal impact of local intervention on a farm. Consequently, more equal meetings are preferable, where the role of the advisor is more of a facilitator than an expert, all participants take an active part, share their knowledge and experiences and trust each other (Ingram, 2008; Evans *et al*., 2017). Klerkx *et al.* (2017) use a typology of farmers due to their interest in using advisory services:

- Pro-activists, who actively seek advice from advisors;
- Do-it-yourselfers, who develop their farming in their own way, for example, by experimenting or seeking alternative sources of information;
- Wait-and-see-ers, who seek advice but implement this to a lesser degree or at a slower pace;
- Reclusive traditionalists, who do what they have always done or think they know best.

Advisors must have professional skills as well as personal qualities, when handling this broad range of personalities. They also need to balance between specialization and universality. The first group, the pro-activists, is considered the optimal one, but also a demanding group to handle (Klerkx *et al.,* 2017). If the advisors do not meet the farmers' needs, there is a risk that they turn to another company, either nationally or internationally, or become a do-it-yourselfers. These characterisations could also be applied on advisor's strategies in relation to CropSAT use.

MATERIALS AND METHODS

Swedish farmers are recommended to fertilise winter wheat one to three times in spring in order to optimise yield and protein content (Albertsson *et al.,* 2016). In order to calculate and apply a variable rate of N, farmers need AgriDSS support using an average amount of N for the target field as a basis. During the spring this amount is reviewed in relation to crop quality and plant stand. In 2015, a new AgriDSS called CropSAT was introduced in Sweden by Focus on Nutrients, a state-funded project aiming to reduce agriculture's environmental impact. CropSAT is an open-access website that uses satellite images to calculate vegetation indices (VI) (Qi *et al.,* 1994) and variable rate application (VRA) files. To calculate a VRA file in CropSAT, the user visits the website and selects a field and a satellite image. The VI is then 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 (Fig. 1) and used to calculate VRA files. The VRA information can then be transferred to the fertiliser spreader via a USB stick. In spring 2017, approximately 4,100 unique users were registered on CropSAT and they normally visited the website two times (personnel information Johan Martinsson, Dataväxt AB).

During 2016 and 2017, the present follow-up study was conducted in which fourteen additional advisors from other parts of Sweden were interviewed to complement the earlier findings (for further details, see Lundström & Lindblom, 2016; 2018).

The participating advisors where purposively sampled (Patton, 2004) by the first author due to their area of interest mentioned on the advisory organization's websites, in order to get as much information as possible from important agricultural regions in the south of Sweden. Some advisors were sampled due to recommendations from their colleagues. The semi quantitative interviews were conducted by telephone (eleven advisors; notes were taken) or in personal meetings (two interviews were recorded). The interview questions concerned the advisors' professional interests in common, what kinds of customers (type of crop production, acreage, technology interest etc.) they have and to what extent and how they used CropSAT in their advisory work. The interviews lasted between 30 and 90 minutes. The recorded interviews were transcribed and all the interviews were compiled and analysed thematically (Patton, 2004). It should be noted that in Sweden farmers pay for most of the extension work to improve agricultural production issues. In this paper, the participating advisors were categorised as independent according to Kuehne's and Llewellyn's (2017) taxonomy because they were either employed by the Rural Economy and Agricultural Societies in different regions or by a private firm, but were not resellers. According to Klerkx's *et al.* (2017) typology they would be considered part of an elitist fraction of the national extension system.

Figure 1a. Vegetation index (VI) displayed on Google Maps, where the user must enter five levels of nitrogen fertilisation compared with the coloured scale.

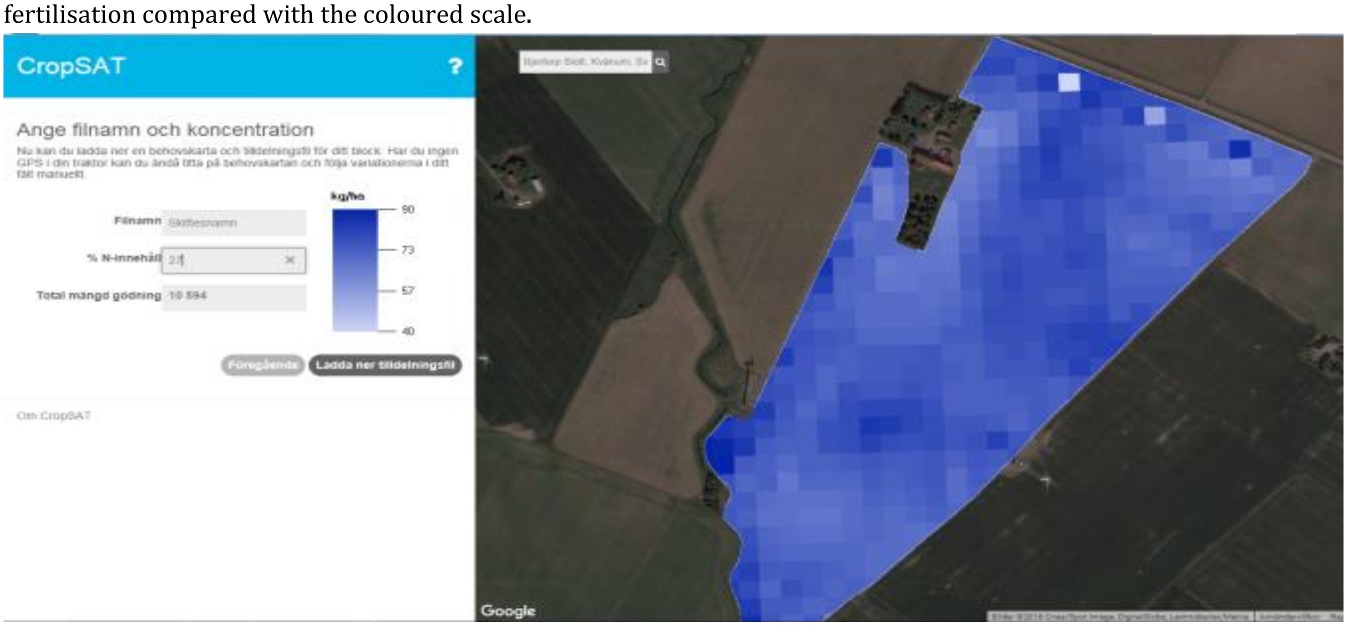

Figure 1b. A variable rate application (VRA) file ready to be entered into the fertiliser spreader via a USB memory stick.

RESULTS

"*First of all you have to get a carrot to pay attention to this… then the farmers require … there are probably those who are skilled and can handle this themselves… but most of them would probably need an advisor who pushes".* Uttered by a PA experienced Pro-activist farmer in a previous project, who together with his colleagues in the company have become Do-it-yourselfers. The obtained results from the interviews conducted with advisors revealed a wide acceptance of the occurrence of within-field variation, familiarity with CropSAT by all participating advisors and an expressed interest for the tool from the majority of advisors. Nevertheless, there were extensive differences in whether and how the advisors used CropSAT in their extension practice. The analysis from the collected data from the interviews revealed four categories of advisor strategy for CropSAT use, where individual advisors were being able to use several strategies:

- I do not use it!
- I will use it if I have to!
- I use it myself and tell the farmer how to fertilise!
- I use it with the farmer!

CropSAT measures a vegetation index that should be related to the actual field. The index in a specific area should be related to the same area in the field and then the user has to decide the amount of N using the same tools as they would when deciding an average amount for the whole field. However, our interpretation of the obtained result is that if the advisors perceive themselves to be experts who ought to provide reliable answers to complex problems, the increased complexity when using CropSAT could then be considered negative.

One user of the first strategy was an advisors in the most productive region of Sweden, who described the situation as:" What *this field needs on an average I think is easier to say ... than what that specific spot should have and that specific spot should have ... Because when you work with general values for the whole field ... then it will be ... largely on average ... and ... yes ... what you think about the yield and so on... But ... it's not as critical ... as when you're going to decide exactly on a specific spot*". Consequently, the answers revealed that it is easier to suggest an average amount for the whole field, knowing that it is not optimal, rather than a specific amount for a specific part of a field. Especially if you do not have access to, do not want to use or do not trust other handheld tools that could support such kinds of technology-mediated decisions. As one advisor said: *"When you do not know, you can as well provide an average amount of N." And:" What is correct, is not very well proved!"*

Another advisor mentioned fertilisation as a difficult intervention: *"It is convenient with customers who say: Yes we fertilised yesterday… because I don't know the true answer".* Our interpretation is that if you consider yourself an expert whose role is to tell the truth, fertilisation is difficult from the beginning and the use of this kind of technology, which increases complexity, could be considered to complicate it further. The answers grouped into the first category seemed to depend on unwillingness to learn, starting to use new technology and change advisor strategies. But, also an addressed uncertainty considering how to relate the satellite image to crop need and consequently how to determine the N demand at a specific spot in a proper way due to a perceived lack of a scientific foundation for the functionality of the AgriDSS CropSAT. Which in turn, this opinion/view was a misunderstanding about the functionality of CropSAT, since the AgriDSS only visualise differences in biomass in order to make it possible for the user to adapt the amount of fertiliser with traditional methods. Using Klerkx's *et al.* (2017) typology of farmers, this group of advisors could be characterised as Reclusive traditionalists, either due to limited interest in new technology and change in advisory practices or due to a sense of uncertainty towards the functionality and scientific rigor of the AgriDSS.

The second identified strategy was used mainly in areas with lower productivity and by a higher proportion of organic and dairy farms. Accordingly, the advisors said that their farmers did not have *"that kind of farm",* the farmers were not interested or *"not so technically advanced"* and "when nobody asks the question, nothing will happen", but *"if somebody do ask, it will be solved".* They waited for the farmers to react and said: *"the customer pushes the development by demand".* This was definitely a group of advisors that could be characterized as so-called Wait-and-see-ers using Klerkx's *et al.* (2017) vocabulary.

The third identified strategy was to use CropSAT when the farmers requested it, but normally not together with the farmer. Instead, the advisors performed the calculations in their offices and provided the farmer with a suggestion for the average amount of N or with a USB memory stick with a CropSAT file. Using this kind of strategy, one advisor said that she could test the AgriDSS by herself in order to know what to say to the farmer, reflecting that she felt that there were expectations that she was an expert who ought to be able to tell the farmer what detailed actions to take. Another advisor said that this strategy was used when the farmer was not interested enough to take part of the discussion, but still wanted to use CropSAT. This strategy could be considered aligned with Klerkx's *et al.* (2017) Do-it-yourselfers, either due to limited support for AgriDSS use from the provider of the AgriDSS or due to farmers' requirements.

The fourth identified strategy was to use CropSAT with the farmer, either in the office or in the field, as a basis for discussion and sometimes for fertilisation. One advisor said: *"CropSAT is part of my concept" but* claimed that every advisor plans their work individually. This group was positive about using other PA tools as well: *"This feels like the right way to go"*. Those advisors constitute a mix of Do-it-yourselfers and Pro-activists using Klerkx's *et al.* (2017) typology. They found their own strategies but did also require information from research. When they experienced a lack of answers from Swedish experts and researchers, they turned to Denmark to find solutions to develop what we described as situated seeing when using CropSAT.

Reflections on results: Our earlier work revealed that when farmers and advisors used CropSAT collaboratively it could be used as a social learning tool and support farmers' situated knowledge and enhance their professional vision (Lundström & Lindblom, 2018). However, the advisor need the cognitive strategy of situated seeing when using the tool in order to be able to facilitate the development of this enhanced professional vision.

The findings from this study revealed that the majority of advisors did not use CropSAT as a social learning tool. We claim that the strategies used by the advisors could also be related to farmers' requests and needs, and advisors' personal interests and doubts about their expertise, knowledge or role. Furthermore, AgriDSS functionality, personal choice and uncertainty about how to use it in practice. When using an AgriDSS such as CropSAT in fertilisation, the complexity increases because there are more parameters to consider. Thus, it could be perceived as more difficult to make correct decisions.

Another option would be to let technology itself solve the problem, by using an expert system. Accordingly, some advisors requested an expert system, providing an optimal N amount for the five levels instead of exchanging experience with the farmer: This aspect was illustrated in the following utterance: "*Now you really need knowledge about the field… and to have a dialogue with the farmer"!* When asked about whether it would be possible for an ICT system to give the exact amount of N demand, one advisor with 25 years of experience answered: *"Yes I really hope so … since I know so little myself …"* Expectations on the technology also increased the demands. *"You want up-to-date satellite images … every, or every other day",* otherwise the advisors did not seem to trust them. Our interpretation is that for some reason they suddenly expected an accuracy in relation to the N amount presented by the AgriDSS that was far beyond the accuracy in the traditional fertilisation strategy with an average ratio of N. Some expressed a difficulty and complexity around making decisions in relation to the crop, but they also expected the technology to manage it much more effectively. They hoped for an expert system or what Black (2000) would call a "technology fix" and obviously, they missed the need for using situated seeing in handling CropSAT.

However, some of the advisors interpreted CropSAT as an AgriDSS. One advisor commented:*"what we have here is a tool that can help you make decisions, however… you can never get a better result than what you tell it to do".* Another one said:" the *technology will never provide the exact truth… which seems to be a problem among my colleagues. However, this is closer to the truth than before*", suggesting that what was needed was:*"a successive change in mind-set".*

In summary, the actors responsible for designing new technology need to provide credible explanations, valid data and advisory strategies to ensure adaptation to farming practice. Farmers need to be acknowledged for their situated knowledge and experience, which is central to increase sustainability. At the same time, they must not consider themselves to be passive receivers of knowledge, but rather accept their responsibility as knowledge providers. Advisors should reconsider their roles as being more of a sounding board or facilitator, taking part in a social learning process than as experts who can provide exact answers. They must also step out of their comfort zone and start introducing technology use in crop production, considering an AgriDSS as a support for decisions and not view it as an expert system. There could be a need for new actors who support the use of technology in the farming practice. However, when using technology as a tool for crop production, agronomy knowledge is essential.

DISCUSSION

This study revealed that the mindset among some Swedish advisors within crop production has changed or is slowly changing from considering the field as a uniform entity to considering within-field variation as something that is worth bearing in mind. We argue that this way of acting is a step towards increased sustainability in large-scale agriculture. When the central basis for fertilisation changes, there is suddenly a challenge to deal with and resolve in order to adapt more effectively to crop need. This could be the first step towards addressing the frustration of, for instance, the European Parliament (2016), which points out that: "the full potential of precision agriculture is not yet harvested. We only see a first series of precision farming practices implemented on small number of farms. These precision farming are making farming more easy rather than giving crop plants and animals the optimal treatment at the right time and lowest scale possible. For the latter, the adoption rate is still very low" (European Parliament, 2016).

Swedish agriculture has faced demands to adapt fertilisation to crop need for a long time, but only at an average level in a specific field. However, all the actors know that there is within-field variation in biomass. Free access to an AgriDSS such as CropSAT makes the variation more obvious, and for farmers who already have convenient technology, it also offers a possibility to do something about it. However, additional knowledge about the field increases complexity and highlights the complicity of finding a true answer. Based on the results, we suggest that there is a need for more back-office support for advisors in order to facilitate their development of situated seeing in relation to technology use, to increase their understanding of the functionality of an AgriDSS, but also back-office discussions about the advisor role. Is the advisor an expert who tells the truth or a sounding board involved in a social learning process? Therefore, a discussion about different expectations from all parts of extension needs to be performed. Traditional crop advisors struggle with their ambition to contribute to improving production, with changes in their roles due to increased complexity and with supporting farmers in using new technology. We recommend a shift from viewing extension as knowledge transfer, towards perceiving it as a joint learning process, where knowledge from both the inside and outside is required. That kind of shift also means that farmers need to consider themselves as knowledge providers not just knowledge consumers (Ingram, 2008). However, this joint learning process probably needs to involve other actors as well, such as researchers, technology providers and, in the case of CropSAT, the government organisation funding the AgriDSS.

Accordingly, an important step to increase the adoption of technology would be a changed mind-set among advisors and farmers, without expecting a technology fix (Black, 2000). Advisors' uncertainty in relation to some technology is somehow understandable since they sell and feel responsible for the advices they provide and will not risk to blindside their customers. PA technology requires support structures to facilitate learning, thus reducing uncertainty and supporting adoption (Eastwood *et al.,* 2017). In the case of CropSAT the technology does not answer the question of how much N the crop needs, it just provides an opportunity to adapt N fertilisation more effectively to biomass variation. The actual amount must still be set by people who use the same tools as those found in traditional fertilisation and those traditional issues are actively discussed among advisors, fertilisation companies and the Swedish Board of Agriculture, supporting the advisors with this kind of information.

Dreyfus (1972/1979, 1992), among others, argued that intelligence and situated knowledge require a background of common sense, with which humans are equipped by virtue of being embodied and situated in their physical, social and cultural world. As a result, it would not be possible to represent human intelligence and situated knowledge within a computer program, as exemplified in an expert system. In a similar line, Evans *et al.* (2017) addressed the need to move beyond R&D methods that strive to provide the precise answer to methods that will facilitate constant improvement in the ongoing social learning process of crop producers, and those who offer expert advice to them. We identify a parallel line of argument to our previous work, where farmers learn how to properly act upon the digital representations provided from CropSAT. Meaning, moving away from knowing how to deal with a certain digital image or *"piece of information"* to making that information being properly used via situated seeing and enhanced professional vision in their farming practices. Consequently, acting in a way that creates added value to them, and in the long-run hopefully cultivates a sustainable agriculture (Lundström & Lindblom, 2016; 2018). However, some voices have been raised arguing that the role of humans in analysis, planning and decision-making in farming practices is further taken over by machines and other smart farming systems of the future, so that the decision-making cycle will be fully autonomous (Wolfert *et al*., 2017). On the other hand, some researchers argued that humans are still being in the decision-making loop "*but probably at a much higher level of intelligence"* (Sundmaeker *et al.,* 2016). Handling big amounts of unstructured heterogeneous data requires "*a smart interplay between skilled data scientists and domain expertise*" (Wolfert *et al.,* 2017) promoting a transdisciplinary approach. Additionally, it would be a cognitively demanding ability to convert and interpret the collected data into available and meaningful pieces of information that could be acted upon, and simultaneously combined with additional historical and several other kind of available data and information (Evans et al., 2017; Sundmaeker *et al*., 2016; Wolfert *et al.,* 2017). We would argue that this higher level of intelligence in form of domain expertise is aligned with what Nitsch (1994) referred to as the coordination ability, which in turn is based on situated knowledge and experience. Thus, the major implication of this study is that different AgriDSS should be used for learning as well as decision-making and considered part of a wider socio-technical system involving different kinds of ICT systems, tools, artefacts and social learning processes. Furthermore, in the case of N fertilisation, every year offers new conditions because automation in a continually changing environment is difficult and demands human supervision.

CONCLUSION

To use AgriDSS to evaluate crop need, the user/farmer/advisor needs knowledge of the crop, understanding of how the technology functions, confidence in the technology and finally situated seeing in order to know how to use it in combination with other information sources and experiences. The requested confidence for new technology is traditionally provided by public research and extension (Eastwood *et al.,* 2017). Crop production advisors have knowledge about crop production. However, the development of 1) enhanced professional vision (interpretations based on technology visualisations) and 2) situated seeing (experience based strategies for combining information sources) for using CropSAT or other AgriDSS, will demand engagement from the advisors as well as increased support from research and back-office in their organisations, otherwise the technology's potential will not be exploited. Better support from external as well as back-office sources, would prevent advisors changing from Pro-activists to for instance Do-it-yourselfers or Wait-and-seers and thus provide higher quality services for farmers. Based on our results, we can identify two major risk scenarios in Swedish agriculture: 1) Pro-activist farmers using new PA technology are not provided with Pro-activist advisors and as a result advisory services is/are refrained, 2) Pro-activist advisors become Do-it-yourselves or Wait-and-seers because they are not provided with the support they may need. Both scenarios would be negative for the innovation capacity in Swedish agriculture. We believe that a change in mind-set among both advisors and farmers is required, in line with within-field variation, technology use and expectations as well as relevant expertise, which all is vital to increase sustainability in agriculture. To manage our addressed change of advisory services, advisor organisations need to develop their back-office work with the aim to jointly develop advisory strategies, in relation to PA AgriDSS (Lundström & Lindblom, 2016; 2018). Advisors also needs to be involved in PA technology development and design to increase its legitimacy and provide a better fit with practice, in the same way that farmers need to be involved (Jakku & Thornburn, 2010; Lindblom *et al.,* 2017; Rose *et al*., 2017). It is widely acknowledged that different kinds of ICT support have come to stay in agriculture and agricultural advisory services, and these technologies need to be further incorporated into the farming practice of both farmers and advisory services. However, different technical support needs to be developed and designed to support the farmer and counselling and not hinder them in their professional practice. There is relevant research in the fields of human-computer interaction (MDI) and user experience design (UXD) that has been used successfully in the development and design of ICT systems in general and in the agricultural domain explicitly (for further details see Lindblom *et al.,* 2017). If support of the individual advisor is becoming more available through back-office as well as from technology developers we would claim that advisors more easily could move from so-called Reclusive traditionalists, Wait-and-see-ers, and Do-it-yourselfers to Pro-activists, which would be of importance in order to increase sustainability in large-scale agriculture. Future research and development is much needed that addresses both farmers' and advisors' requirements for better support in their social learning processes of using AgriDSS and developing their situated seeing in order to take the next step in PA. It should be mentioned that we fully agree with Evans *et al.* (2017) who reject the term *"decision agriculture"* because the current use of the term appears to imply that on-farm decision-making will be improved solely by better access to site-specific, data driven information according to them. Accordingly, farmers and advisors are still making the similar decisions as before, albeit at an increasingly finer scale, through the use of PA technology. Hence, we want to stress the need to also include the social and learning dimensions in the decision-making loop, because AgriDSSs and other ICT systems only provide a means for cultivating sustainable practices, which can affect practices on individual and group level, but also affect societal values and policies. Thus, in the long run, developing and cultivating sustainable farming practices. A sustainable society ultimately depends on the resources it can muster in terms of human resources, and an important means towards the goals of sustainability is through farmers', advisors', and technology developers' everyday practices (Susi *et al.,* 2014). Sustainability cannot be transferred to, or induced upon their learners–it has to come from 'within', through individuals embracing sustainable practices in order to gain sustainability of the everydayness of farming life that includes the whole agricultural knowledge and innovation system, from a socio-technical perspective.

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