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Considering farmers' situated knowledge of using agricultural decision support systems (AgriDSS) to Foster farming practices: The case of CropSAT

Christina Lundström[a,*], Jessica Lindblom[b]

[a] Swedish University of Agricultural Sciences, PO Box 234, SE-532 23 Skara, Sweden
[b] University of Skövde, Skövde, Sweden

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ABSTRACT

Precision agriculture is an important part of the sustainable intensification of agriculture, where information and communications technology and other technologies are necessary, but not sufficient for sustainable farming systems. The technology must fit into farmers' practice and be handled by their experienced-based, *situated knowledge* in order to contribute to increased sustainability in their farming. This study analysed the relationship between farmers' experience-based situated knowledge and the use of agricultural decision support systems in order to develop *care* by farmers in their practice. The theoretical framework of distributed cognition was used as a lens when investigating and analysing farmers' use of an agricultural decision support system called CropSAT developed for calculation of variable rate application files for nitrogen fertilisation from satellite images. In the case study, the unit of analysis was broadened to the whole socio-technical system of farmers' decision-making and learning, including other people and different kinds of tools and artefacts. The results revealed that social contexts could support farmers' development of cognitive strategies for use of agricultural decision support systems, e.g. CropSAT, and could thus facilitate decision-making and learning through development of *enhanced professional vision* that hopefully may increase farmers' situated knowledge and care in PA.

1. Introduction

It is acknowledged that precision agriculture (PA) is one part in a sustainable intensification trajectory where information and communications technology (ICT) and other technologies are necessary to increase sustainability of large-scale farming systems (Aubert et al., 2012; Lindblom et al., 2017). Sustainable intensification has to harness the complexity of a wider range of agro-ecological and socio-technological processes (Garnett et al., 2013), in order to "*more than doubling of the agri-food production while at the same time at least halving our ecological footprint*" (Sundmaeker et al., 2016, p. 130). To increase sustainability in agriculture we need knowledge that is *complex, diverse* and *local* (Leeuwis, 2004). Various kinds of ICT systems in PA are expected to be contributors in handling a higher complexity as well as an increased local adaptation (Aubert et al., 2012). PA can be viewed as a farm management concept based on observing, measuring and responding to within-field variations in both temporal and spatial components. Earlier it was complicated to respond in an effective and reliable way, instead measurements were used for calculation of an average need for each field of for instance nitrogen. Hence, PA technology provides possibilities for farmers to recognise and handle within-field variations to a much greater degree than ever before (Aubert et al., 2012; Wolfert et al., 2017). Better adaptation of field measures to crop requirements may decrease sub-optimal treatments, which in turn hopefully increases profitability due to higher efficiency in usage of inputs and land, better crop quality and a decrease in negative environmental impact (Lindblom et al., 2017).

In order to perform PA, certain kinds of ICT systems, known as agricultural decision support systems (AgriDSS), have been developed. However, many available AgriDSS are for several reasons poorly adapted to farmers' needs and practices and thus not exploited to their full potential (e.g. Jakku and Thorburn, 2010; Lindblom et al., 2017; Matthews et al., 2008). Important reasons are that the questions of AgriDSS design and usability are not regarded as central issues in the agronomic research community, even though the lack of credible and usable AgriDSS is viewed as a major problem (Prost et al., 2012). Technology development is often based on what researchers and developers of AgriDSS consider usable and credible and therefore not adapted to farmers' actually needs and practices (see Lindblom et al., 2017 for a detailed review of these topics). As pointed out by Röling (1988) technology should not be considered an isolated phenomenon. Instead of developing an AgriDSS as a straight operational tool to

* Corresponding author.
E-mail addresses: christina.lundstrom@slu.se (C. Lundström), jessica.lindblom@his.se (J. Lindblom).

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support farmers in making decisions, many researchers highlight the possibility of using an AgriDSS as a social learning tool that can facilitate discussions and promote learning among different stakeholders (e.g. Hochman and Carberry, 2011; Jakku and Thorburn, 2010; Matthews et al., 2008; McCown, 2002; McCown et al., 2009; Thorburn et al., 2011). Used in this way, an AgriDSS could frame a change from goal-orientated thinking to thinking in terms of learning (Schlindwein et al., 2015). Schlindwein et al. (2015) proposed that in high complexity situations, as e.g., adaptation to climate change, crop-models should not be used as an isolated tool for deterministic, specific answers, i.e. goal-oriented thinking. Instead they should be integrated in a wider learning system, i.e. thinking in terms of learning. This kind of learning approach, is the perspective we take in this paper.

The present study examined how an AgriDSS for PA called CropSAT could provide possibilities to support and promote farmers' decision-making and learning in situ, studying them in the socio-technical system. The overall aim was to increase the understanding of the relationship between farmers' experience-based situated knowledge and the use of AgriDSS in order to develop farmers' *care* in PA, in the sense used by Krzywoszynska (2015). She characterised care as "*the result of all practices that make technology and knowledge work*" (2015, p. 290).

The theoretical framework of distributed cognition (DCog) (Hutchins, 1995) was used as a lens when investigating and analysing farmers' use in practice of CropSAT, an AgriDSS for PA which enables variable rate application of nitrogen. With this view on PA as a complex socio-technical system, the need to study both cognitive and social activities in practice becomes evident, and also the need for incorporation of external resources that are available to perform a PA practice. The DCog framework (Hutchins, 1995) is one of the most prominent *research-in-the-wild* (RITW) approaches that were introduced nearly three decades ago. Hutchins (1995) started to write about cognition being-in-the-wild, stressing that e.g. decision-making and learning - when being observed as it unfolds in practice – is distributed and embodied in the social and material sphere and situated in the moment (Rogers and Marshall, 2017). A key concern in RITW studies is to reveal what actually happens in the real world, how do humans act and behave in situ, what kind of material and social resources do they use, when, and in what ways? When contrasting RITW approaches to quantitative studies where researchers try to hypothesise and predict human performance, running in situ studies often provides unexpected findings and uncovers insights about human actions in practice beyond the scope and grasp of more traditional research approaches. In other words, it is argued that RITW uncovers the unexpected rather than confirming hypotheses or aspects already known (Rogers and Marshall, 2017). Rogers and Marshall (2017) point out that this way of conducting research may at first glance be viewed as if it is lacking the rigor associated with the more dominated research paradigm of conducting behavioural studies. However, despite the lack of control and randomized sampling in RITW studies, it is argued that this approach can be the most revealing when it comes to discovering what actually happens in the real world by studying more deeply just a few numbers of participants that are purposely sampled. These studies also provide a greater ecological validity compared with inferring result from more quantitative studies (Rogers and Marshall, 2017). Therefore, the outcome from RITW studies can provide new insights and understandings of human behaviour in the real world where technology is embedded and used in everyday life, and it is stressed that RITW studies is becoming more widely accepted as a way of doing research when studying e.g. human cognition, human-technology interaction, and human-computer interaction. In this way, RITW is complementing but also questioning the validity of the traditional quantitate research paradigm (Rogers and Marshall, 2017). This way of performing studies in PA, may in the long run hopefully promote a more sustainable farming practices.

The remainder of this paper is structured as follows: A background section provides a description of the individual's role in promoting a sustainable transition in the agricultural domain, in relation to AgriDSS as learning tools that motivate and frame the work discussed in this paper. This section also presents theories on decision-making concerning such processes in practice, and introduces the theoretical framework of DCog. Subsequent sections outline the chosen empirical approach and the findings. The paper ends with a discussion, some conclusions and a list of implications for PA.

2. Background

At the core of the transition towards sustainable intensification in agriculture is the individual decision maker, making strategic, tactical and operative decisions bridging theory and practice and balancing the desirable with the feasible (Matthews et al., 2008; Van Meensel et al., 2012). Farmers' daily work activities are complex because they require knowledge and consideration of a wide range of biological, technological, practical, political, legal, economic, ethical and social factors and circumstances (e.g. Lindblom et al., 2013; Nitsch, 1994). During this knowledge development process, a broad range of different individual and social learning situations are of major importance in influencing the farmer. They develop operating skills to *know that* action is required, *know what* to do, and also *know how* to do it, even if it is clear to them that the actions they perform will not always be optimal (Baars, 2011). It is argued that farmers learn in action through a kind of lifelong longitudinal case study set-up, which means that their learning process is more experiential than experimental (Hoffmann et al., 2007).

2.1. Situated knowledge, care and technology in farming practice

Comparisons with formalised knowledge and results obtained in earlier years and in different places are made either consciously or unconsciously by farmers, in order to form new knowledge and rules of thumb for their work. Thus, experienced farmers could be considered experts on their own farms and are in possession of a considerable amount of so-called intuitive, situated knowledge (Clancey, 1997; Hoffmann et al., 2007; Lindblom and Lundström, 2014). The concept of situated knowledge can briefly be defined as knowledge based on experience and is to a certain extent a product of the activity, context and culture in which it is developed and used (Brown and Collins, 1989). Accordingly, Dreyfus (1992) 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 or an AgriDSS.

In relation to agriculture, Krzywoszynska (2015), for example, claimed that this kind of embodied, experiential and situated knowledge is central for the development of the multiple *care* aspects that society is increasingly expecting and demanding from agriculture. However, in this sense care is not considered an obligation, a principle or an emotion, but "*the result of all practices that make technology and knowledge work*" (Krzywoszynska, 2015, p. 290). Accordingly, Mol et al. (2010, p. 14) remarked that good care could be described as "*persistent tinkering in a world full of complex ambivalence and shifting tensions*". This means that care is not something a person learns by imitation, but rather is "*infused with experience and expertise and depends on subtle skills that may be adapted and improved along the way when they are attended to and when there is room for experimentation*" (Mol et al., 2010, p. 14).

Good care requires situated knowledge based on *attentiveness*, *responsiveness* and *adaptation* to constantly changing circumstances, as is the case in farming practice (Krzywoszynska, 2015). The actor, i.e. the farmer, must recognise the problem, feel responsibility and have the competence to act upon it. Therefore, it is of major interest to acknowledge and promote the role of farmers' situated knowledge in order to develop care in farming practices and thus to increase sustainability.

According to Nitsch (1994, p. 30), the very core of farm