What drives adoption of smart farming technologies? Evidence from a cross-country study

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Abstract:

Technological innovations are currently taking mechanisation in agriculture to another level, preoccupying farmers, technology providers, politicians and researchers working in the sector. This wave of innovations, often referred to as smart farming technologies (SFT), also fuels the more general debate in both research and society about how we want to produce food in the future. To better understand the underlying processes of the ongoing technological progress and its relevance to farming systems across Europe, here, we are exploring: (1) who are the farmers that adopt digital innovations, (2) what supporting factors and barriers do they perceive and within this context, (3) which actors and sources of information are supportive and how? Empirical data from a farmer survey conducted in France, Germany, Greece, the Netherlands, Serbia, Spain and the United Kingdom indicate that practitioners have a differentiated perception of SFT potential to improve farm work and farm impact on the environment. Expert interviews reveal a (perceived) regional divergence in the current EU policies regarding investment in SFT and thereby simultaneously support and hindering the innovation and adoption process. Farmers and experts both deplore the lack of impartial advisory services were deplored, suggesting potential for this institution. In general, farmers throughout Europe identify similar barriers for the adoption of SFT, namely the cost of SFT, the lack of compatibility between devices and an improvable transformation of collected data into usable and accessible information. Farmer-to-farmer communication is one of the most important sources of information, across all countries included in the study.

Keywords: *smart farming technologies, technological innovations, driving forces, farmers' perceptions, digitisation, innovation process, Europe*

Introduction

Agricultural innovations are currently taking mechanisation in agriculture to another level, preoccupying farmers, technology providers, politicians and researchers working in the sector. Such new technologies on farms - often referred to as smart farming technologies (SFT) – promise to, for example, reduce costs through applying inputs (fertilizer and plant protection agents) based on the actual needs of soil and crops, thereby reducing the environmental impact of the farm (Basso et al., 2016). In the case of autonomous robotic vehicles, SFT are expected to increase manpower efficiency per hectare and working comfort through automatization of monotonous work processes (Pederson et al., 2006). Moreover, new digital models for farm management information systems (FMIS) offer an easy way to document all farm-related processes and comply with the required documentation connected to EU regulation (Fountas et al., 2015). Nevertheless, how SFT can be implemented to improve sustainability at the farm level to meet respective standards and expectations don't seem to be either assessed nor communicated adequately (Coteur et al., 2016).

Farmers across Europe are not hooked by SFT - their adoption is clouded by skepticism and hesitancy (Reichardt and Jürgens 2009). The question arises, whether and why farmers do or do not perceive SFT as a means to overcome the economic, social and environmental challenges they face. Previous research shows that farmer demographics (e.g. age, education) play less of a role than do their perception and attitudes regarding the farm and technology (see Kernecker et al. 2016, Tey and Brindal, 2012). Due to the particularity of technological innovations being relatively new on the market, and their fast turnover, it can be assumed that knowledge and experience about SFT is rather limited. This makes access and reliability of information a bottleneck for farmers, leading them to weigh all pros and cons of new technologies in comparison to traditional ones, especially in regard to their needs and interests. Nevertheless, we assume that sources of information are only one of many aspects influencing farmers in the course of decision-making regarding innovations like SFT. Thus, here we explore how farmers' preferences, interests and choices influence the interest in or adoption of SFT.

Innovation theory provides a number of explanations why or why not innovations (whether technological, social, or other) are adopted. On one hand, innovation characteristics themselves could be instrumental to determining their adoption rate. There are five characteristics of innovations – as perceived by individuals – that may explain the rate of innovation adoption: (1) Relative advantage is how much better an innovation is perceived to be compared to the preceding idea, technology, or method; (2) Compatibility describes how much an innovation is perceived as being consistent with values, past experiences, and needs of potential adopters. If an idea is incompatible, it won't be adopted as quickly; (3) Complexity reflects how difficult to understand and use an innovation is. The more complicated an innovation is, the more slowly it is to be adopted; (4) Triability is the degree to which an innovation may be experimented with and then adopted on an incremental basis, rather than all at once. This serves as a sort of insurance; (5) Observability is the degree to which the outcome of an innovation is visible to others. If results are easily visible, then the innovation is more likely to be adopted (Rogers, 2003). Exploring these characteristics of SFT as perceived by farmers and experts in the agricultural sector can tell us why or why not SFT are relevant to farmers.

On the other hand, the innovation process itself is shaped by key supporting factors and barriers that contribute to the innovation adoption and diffusion. An innovation can be understood through the process of related behavioral change that occurs over time in which an innovation is embedded. To describe this change-process, a three-stage model of voluntary change of behaviour was developed by Lewin (1942), highlighting fostering and hindering forces of innovations. This model can be applied to many social structures and organizations. It was adjusted for use in the context of agricultural advisory systems by Hruschka (1994), Albrecht et al. (1987) and Hoffmann et al. (2009) where it supports the focus on subjectively perceived factors. We use this model in combination with a second one, which is the popular scheme from Roger (2003:170ff) who distinguishes 5 phases of the (individual) innovation process: awareness creation (knowledge), persuasion, decision making, implementation and confirmation. Here, the first step of awareness creation is seen as influenced by a number of factors such as individual socio-demographic and structural factors, personal characteristics and the influencing social system through shared norms, values etc., while the second step of trial persuasion can be conceptually linked to the above-mentioned innovation's characteristics. The strength of this latter model is that it specifies and comprehensively structures the various factors influencing the innovation process, while the advantage of the former model is the way in which it accounts for the subjectively constructed, psychological factors in the decision-making process regarding innovations (Hoffmann et al. 2009).

We based the design of our empirical approach on these concepts with the aim to explore:

- Who are the farmers that adopt SFT innovations?
- What supporting factors and barriers (in terms of SFT characteristics and behavioural change driving and hindering factors) do they perceive?

- Which factors from the wider environment, such as social actor (group)s and sources of information, are supportive and how?

To study these questions in detail, we used a methodological approach that combined a farmer survey with a number of expert interviews, to explore farmers' perceptions of and attitudes towards SFT.

Methods

Empirical case study

To explore the relationship between farmers' perception of supporting and hindering factors of SFT adoption, we rely on data gathered within the context of the European H2020 project Smart-AKIS (www.smart-akis.eu). By focusing on innovation processes in agriculture, one central aim of the project is to identify farmers' needs and interests with regard to digital and smart farming technologies and to investigate factors affecting the generation, adoption and diffusion of SFT. Smart-AKIS has partners in 7 different European countries: France, Germany, Greece, Serbia, Spain, the Netherlands, and the UK which were all involved in the conduct of the farmers' survey.

Sampling

Farmer survey

The survey was designed and prepared by the team of the authors and implemented in cooperation with the other Smart-AKIS partners in 7 EU countries at a regional level. Our sampling of farmers was not representative, since contact was established through each of the regional partners, using pre-established networks with in their regions. The sampling followed a purposive scheme were we combined a) 4 different cropping systems of a certain national importance in each of the 7 countries, b) a selection of farms from all size classes, c) adopters and non-adopters of SFT, and d) a wide range of ages. The aim of this purposive sampling was to allow for the construction of potentially similar groups across regions. We aimed to conduct surveys with 5-15 farmers from the most relevant size classes for each cropping system (Table 1).

Table 1: Target range of number of farmers to interview in each regional hub, in each cropping system.

	France	Germany	Greece	Netherlands	Serbia	Spain	UK	Total
Arable	5-10	25	5-10	5-10	10-20	5-10	10-20	**65-105**
Orchards	5-10	0	5-10	5-10	10-20	0	0	**25-50**
Open field vegetables	5-10	0	5-10	5-10	0	5-10	10-20	**20-60**
Vineyards	5-10	0	0	0	0	5-10	0	**10-20**
Total	**25-30**	**25-30**	**25-30**	**25-30**	**25-30**	**25-30**	**25-30**	**175-235**

Expert Groups

To complement the farmers' survey, we conducted interviews with experts from 3 professional groups relevant to agricultural technological innovation processes, namely research, industry and practice. Overall, we conducted 22 interviews with experts from 9 European countries. Actors from the expert group *research (8)* are affiliated to universities,

universities of applied science or research institutions. The group *industry (10)* is represented by experts from businesses providing agricultural IT and machinery. Representatives from the expert group *practice (4)* are affiliated to administration, journalism and agricultural associations (Table 2).

Table 2: Number of Experts interviewed in each country and in each expert group.

	Industry	Practice	Research	Total
Denmark			1	1
France	1		1	2
Germany		1	2	3
Greece	2	1	1	4
Netherlands	4	1	1	6
Serbia		1	1	2
UK			1	1
International	3			3
Total	10	4	8	22

Data collection

Questionnaire and conducting farmer survey

The questionnaire for the farmer survey was designed to gather information regarding the 1) farm, 2) farmer-specific knowledge, opinions, and attitudes towards farming and technology, and 3) farmers' socio-demographics (e.g. age, education), and values (see Kernecker et al., 2016). Farmers were asked to disagree or agree with statements representing different points of view (e.g. using a forced choice Likert Scale), were asked to rank certain issues or statements (on a 1-5 scale), were provided with multiple-choice answers to simple questions, and had the opportunity to respond to a few open questions. In total, there were 129 individual items in the questionnaire (see Kernecker et al., 2016).

Here, we here rely on the survey items that specifically address adoption, adoption potential (whether or not farmers have sought out information on SFT) and the relationship between supporting and hindering factors and SFT adoption. To identify supporting factors for SFT adoption potential, we asked farmers to decide on how much they did or didn't agree with statements based on selected SFT. Specifically, we asked them if they strongly disagree, disagree, agree, or strongly agree with SFT being useful for farming, being better compared to the technology or tools that were available before, increases productivity compared to not using it, decreases input costs compared to not using it, provides information to help make better management decisions, helps reduce pollution from farms, improves the impact of farms on nature, improves farmers' work processes and workload, improves farmers' work comfort, and improves farms' income. We also asked farmers about technology in general. To explore the factors that may hinder SFT uptake or adoption, we asked farmers how important it would be to improve a variety of technical and structural/social aspects related to SFT use. Specifically, we asked farmers to rate improvements to make SFT more relevant from 1 to 5, 1 being least important, and 5 being the most important. These statements reflect innovation characteristics as described by Rogers (2003). We complemented this question with a short open question to find out what kind of improvements is needed. By asking about what needs to be improved, we assumed that these aspects were hindering SFT adoption.

The questionnaire was pre-tested with farmers in July 2016 in each participating region. Notes on sensitive, unclear, and unnecessary questions, survey structure, and length were taken into account and used to finalize the questionnaire. The surveys were conducted face-to-face or via telephone, and responses were transferred to a master excel file via a Google Form. Only partners were allowed access to the form. Each farmer was provided with an accompanying letter ensuring the anonymity of the data collected. We used methods for preparing and conducting the survey according to Babbie (2015).

Guideline expert interviews

The interview guide was structured thematically and aligned with the factors affecting innovation adoption and diffusion processes, dividing them into socio-demographic, economic, political and societal factors that foster and/or hinder the use of SFT. The list of questions was elaborated and utilized as a guideline throughout the expert interviews. Specifically, the questions addressed a) the future of agriculture and its challenges in Europe, and the role of SFT in this context; b) aims of innovation in agriculture as well as drivers behind the innovations; c) individual factors that motivate farmers' adoption of SFT, referring to interests, background, their information and education system as well as farm properties; d) the role of different actor groups (farmers, developers, retailors, politicians, scientists, etc.) in shaping direction of innovations, as well as their interaction; e) change of societal values or interests shape SFT adoption/interest on the farmers' side and f) political influence and strategies on the innovation and adoption of SFT (Borges et al., 2017). The expert interviews were semi-structured, such that the interview guide was adapted to each of the experts being interviewed (Newing, 2011). The interviews were conducted face-to-face, via telephone or Skype.

Data analysis

Farmer Survey

All survey data was entered into a Google Form to streamline data management. Data was downloaded from the form as a spreadsheet and used for analysis. The data had very few instances of non-response. The data set (n= 287) was analysed using descriptive statistics to help portray trends of attitudes towards SFT and their adoption across countries, cropping systems, and farm sizes. Furthermore, to test the effect of country, cropping system, farm size, and age on adoption, Kruskal-Wallis test was used. A post hoc analysis for differences between explanatory factors was used with Dunn-Nemenyi tests using Chi-square differences to adjust p-values for ties that are common in ordinal and binary data. A paired student's t-test was used to evaluate if there were differences between farmers who sought out information on SFT or not, according to whether or not they were adopters. Quantitative data was complemented with qualitative analysis of short open answers using an open coding technique, which essentially is a form of annotation in the text (Newing 2011).

Expert Interviews

The recorded statements of the experts were transcribed using the f4transkript (Version 6.2.3 Pro) software, and done according to the simplified transliteration guidelines by Dresing & Pehl (2015). Qualitative Content Analysis (QCA) using MAXQDA (Version 10) software was utilized for coding and categorizing the transcripts. QCA is a flexible method, which is focused on the specific research objective (Mayring 2010). Specifically, we used the content-related structuring with deductive category assignment according to Mayring (2014) to extract the valuable information from the interviews.

Results

Farmers surveyed: adopters and non-adopters

In total, 287 farmers participated in the survey among which only 19 women. The most farmers (n=68) were interviewed in Greece, and only 28 farmers were interviewed in both Germany and Spain. Of all farmers, there were 144 SFT adopters and 143 non-adopters. The farmers that participated in the survey were also highly educated, 37% have attended the university and 22% have some sort of technical training. 35% of the farmers included have secondary school education (defined as 8-12 years of general education), and 6% have an elementary school education (defined as up to 7 years of general education).

There were significant differences between countries (χ^2= 84.7, df = 6, p < 0.0001), farm size (χ^2 = 89.9, df = 6, p < 0.0001), and cropping system (χ^2 = 26.2, df = 3, p < 0.0001) in adoption. Greece and Serbia had significantly lower rates of adoption than Germany, the Netherlands, and the UK. We also found that among our sample of farmers, the larger the farms, the greater the adoption rate, such that farms under 10 ha had significantly less adopters than farms that were 101 ha and larger. Farms that were over 500 ha were exclusively adopters. Arable farmers had a significantly higher rate of adoption than both tree crop and vineyard farmers. Farmers' age had no effect on adoption (χ^2 = 6.1, df = 4, p-value = 0.2).

Table 3: Stratification of farmers surveyed. The number of adopter (A) and non-adopters (NA) are listed according to farm size class, and both country (above) and cropping system (below).

	Hectare														
	0-2		**2-10**		**11-50**		**51-100**		**101-200**		**201-500**		**> 500**		
Country	**A**	**NA**	**A**	**NA**	**A**	**NA**	**A**	**NA**	**A**	**NA**	**A**	**NA**	**A**	**NA**	**Total**
France	0	0	2	8	3	7	3	6	8	6	0	4	0	2	**49**
Germany	0	0	0	1	1	0	3	1	2	1	5	0	14	0	**28**
Greece	0	9	14	33	3	7	0	2	0	0	0	0	0	0	**68**
Serbia	1	3	2	17	1	6	1	5	0	0	0	0	0	0	**36**
Spain	0	0	0	1	4	10	2	1	5	4	1	0	0	0	**28**
Netherlands	0	0	2	1	12	2	6	5	9	3	4	0	0	0	**44**
The UK	0	0	0	2	0	1	1	0	4	0	6	1	19	0	**34**
Total	**1**	**12**	**20**	**63**	**24**	**33**	**16**	**20**	**28**	**14**	**16**	**5**	**33**	**2**	**287**
Cropping System															
Arable	1	3	2	10	6	6	10	15	21	11	18	1	29	0	**133**
Tree	0	8	6	21	7	4	0	0	0	0	0	0	0	0	**46**
Horticulture	0	0	0	9	3	7	4	4	5	2	2	0	6	0	**42**
Vineyard	0	1	12	23	8	16	2	1	2	1	0	0	0	0	**66**
Total	**1**	**12**	**20**	**63**	**24**	**33**	**16**	**20**	**28**	**14**	**20**	**1**	**35**	**0**	**287**

A paired student t-test revealed that farmers who were adopters did not seek information regarding SFT, and farmers who were not adopters did seek information on SFT (t = 5.2, df = 566.1, p-value <.0001).

Experts that were interviewed had contested opinions about the role of farmer age and farm size in regard to SFT adoption. Regarding age, one expert from Spain portrayed a disparate situation: "we have a polarized market now in Spain, a few amount of farmers which are investing in new technologies and a big amount of farmers which are investing in used equipment in order to survive. The average age of the farmer, of that kind of farmer is increasing, they are not in the mood of continuing their work, their kids are leaving the little towns to go to the cities, so why to invest in new technologies?" One expert from Germany addressed the relationship between size and adoption: "Of course big farms will more probable adopt the technology to deal with all the work on a big farm without spending much costs on labour. But this is exactly the opposite of small scale farms in rural areas which keeps people or find other infrastructure or other industrial sectors.” An expert from Greece suggested that the financial ability to invest in SFT was a key point, “because in Northern Europe where farmers are having mostly bigger farms, so bigger incomes. So it´s more easy for them to, to give some money for some new equipment or ideas, or applications etc. (…) When you have a big farm, the money is quite big. (…) In Southern Europe, because we´re having smaller farms, in Greece, Spain … or Balkan so - the incomes of the farmer are smaller, so in order to … buy something like that, it must be relatively cheap.” However, another expert expanded on this view by stating, “it has to deal not exactly with their farms’ size, (…) because it depends on the crop. Because high value crops, maybe you have 20 hectares with high value crops like, like olive oils etc. and the incomes to be very good. Or maybe you have 20 hectares of wheat and you don´t have any good income - so (…) I cannot tell it farm size or crop size - it´s combination of that.” In northern Europe where farms are larger, size and SFT adoption or use are explained by a lack of skilled labor, as explained by a farming expert from the Netherlands. “[A] decrease of qualified people in the whole agriculture business (…) So, if we want it or not in the next coming 10 years the farms will grow or will expand, but the people who are responsible for all the work will not expand in that amount. So we need (…) techniques to get more output from the people who are left.”

Supporting factors for and barriers to SFT adoption

To assess fostering factors for SFT adoption, we asked farmers if they agreed or disagreed with statements regarding what SFT can do for them as they face different challenges, and their attitude about technology in general. We hypothesized that farmers would adopt or use SFT largely because they agree that SFT are capable of dealing with a number of on-farm challenges. Farmers agreed with the statements that SFT are useful for farming (97%) and better than the technology and tools that were available before (94%). While SFT are perceived as also largely increasing productivity and improving work processes, load, and comfort (86%), farmers show the largest disagreement with the statements that SFT will improve the farm’s impact on nature (32%), reduce farm pollution (24%), and improve farm income (23%, Fig. 1).

Almost all farmers were convinced that technology in general could improve farming (97% of responses), and that in a large part would help farmers comply with regulations (85% of responses). The opinion that SFTs may support farmers’ recognition of work by public got a little less approval by roughly 77% of the interviewees.

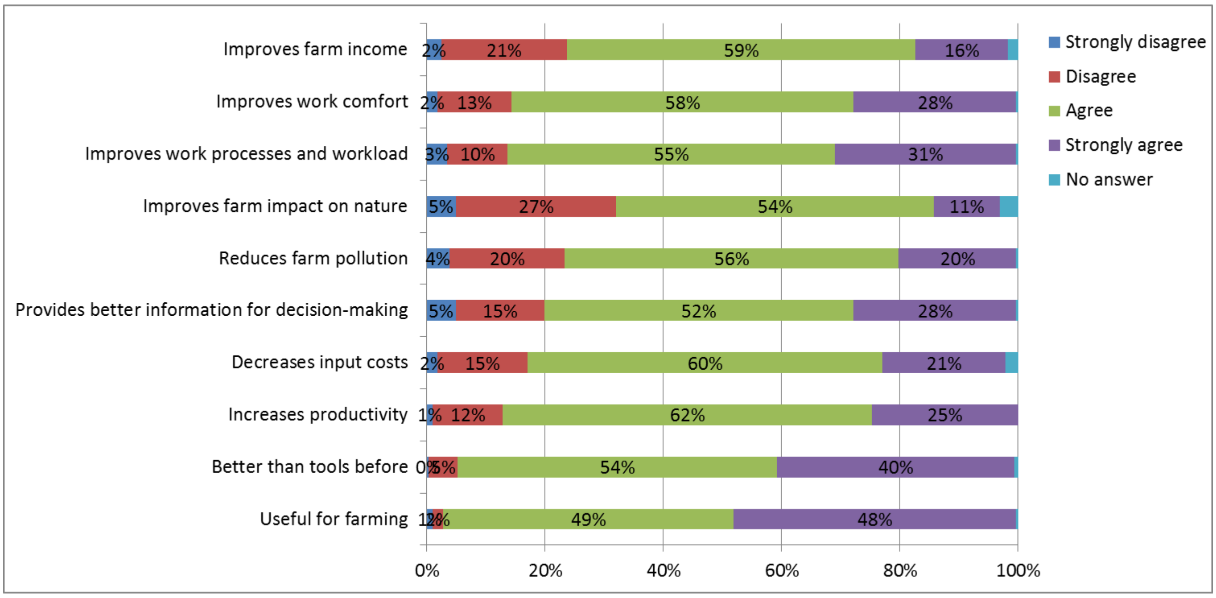

Figure 1 Farmers opinion about SFT potential to help them deal with on-farm issues.

Experts consider farmers' motivation to increase farm productivity either in quantity or quality as one key factor for farmers' SFT use. A second frequently mentioned driver is the intention to decrease the quantity of inputs (water, fertilizer, plant protection, etc.) or to simultaneously either reduce costs or to ease labour, which address the innovation characteristic 'relative advantage'. Another important aspect and incentive for SFT adoption, according to experts, is to comply with governmental regulations as well as with regulations of certification systems to increase the value of their products. Experts considered EU funded projects and national strategies as supportive to the development SFT and to farmers' adoption of SFT, except in southern Europe.

Some experts – particularly those in north-west Europe – stated that society's increasing awareness towards environmental issues contributes to great acceptance regarding SFT use. This view was not shared by experts froms south-east Europe. This latter group largely agreed that the economic situation in those countries prevents such shifts in awareness and that there are corresponding impacts on expectations of farmers.

We asked farmers about barriers to SFT adoption based on innovation characterstics that would make SFT more relevant to farmers. We asked them to rank these aspects of SFT adoption to make them more relevant to farmers (1 not crucial to 5 very crucial). For example, improving data storage options reflects relative advantage of SFT over previous technologies. Asking farmers how they rank the importance of improving data presentation for better decision support, reflects the relative advantage of SFT innovations. This ranking also indirectly reflects an innovation's complexity, since it underlines how difficult SFT are to use. Improving social networks for more access is linked to both triabilitity and observability, since social networks enable communication of information and potentially provide farmers the opportunity to try out available SFT or observe their in-field effects on other or demo farms. Improving data interoperability reflects the compatability of SFT innovations since the SFT should be consistent with farmer needs and the technology that they already have. Improving user safety somewhat reflects triability, since safety or sense of safety is a pre-requisite to using technologies.

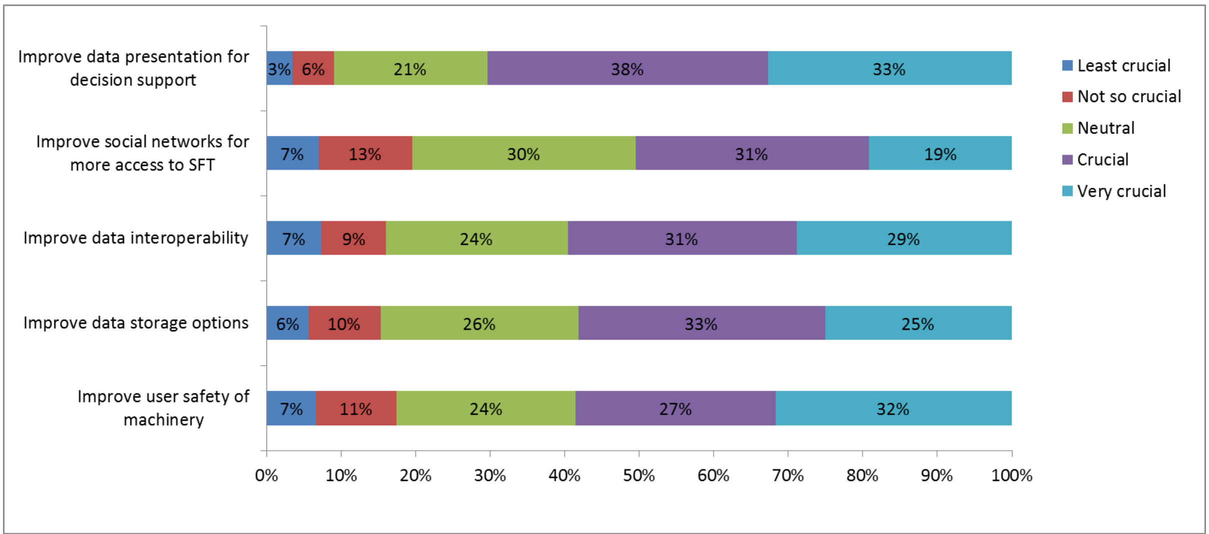

Figure 2 Farmers' ranking of potential hindering factors for SFT adoption or dissemination.

To make SFT more relevant and important for farmers, most farmers (71%) across Europe concluded that it was crucial that SFT should improve data presentation for better decision-support. It was the least crucial (20% said it was not crucial, and 30% were neutral) that social networks for more access to SFT should be improved.

We also asked farmers open questions listing improvements they would make to SFT, to make them more acceptable or useful for farmers. In total, 171 farmers (60%) provided suggestions for improvements. We grouped most of the farmers' responses into 4 categories:

- Enhancing access (45 times, 31% of responses):
  - Improve access to information about SFT (i.e. cost-benefit models) (16 times)
  - Reduce cost (23 times)
  - Infrastructure (i.e. internet connection, satellite imagery) (6 times)

- Improving the technology system (32 times, 22% of responses):
  - Simplification and consolidation of SFT and apps (8 times)
  - Compatibility between devices (24 times)

- Improving the device (36 times, 25% of responses):
  - Efficiency (11 times)
  - Reliability (7 times)
  - Reduce complexity (16 times)
  - Device adaptation (i.e. size reduction, transferability to another cropping system) (2 times)

- Enhancing data management and usability (33 times, 23% of responses):
  - Data mobility (i.e. with tablets or smart phones) (9 times)
  - Data transfer between devices (i.e. from computer to tablet or smart phone) (12 times)
  - Make the transformation of data into information better so that it can improve decision-support in the field (i.e. improve data presentation) (10 times)
  - Data security (2 times)

The 4 main groups of suggestions include SFT access, the technological system as a whole, the device level, and the data level. Access to SFT was the most frequently mentioned – a large barrier to adoption seems to be the cost of SFT. At the level of the technological system as a whole, farmers' statements suggested that compatibility between devices, or lack thereof, is a major hurdle for SFT success.

Farmers across Europe, both adopters and non-adopters, agree that barriers to use SFT can be attributed to innovation characteristics: including high costs (issues of trialability), complexity, lacking appropriateness for farming contexts (no observability possible, because SFT do not fit into their region, community, or larger social and natural environment), interoperability (compatibility), and precision (relative advantage). Moreover, SFT frequently lack a clear added-value to farms, and also lack accompanying information or advice that is neutral (observability and trialability) (Table 4).

Table 4 Barriers to using and/or adopting SFT according to non-adopters and adopters.

Non-adopters	***Adopters***
High investment costs	High investment costs
Too complex to use	Too difficult to interpret data
Technology not appropriate for farm context and size	Devices are not interoperable and not precise enough
Unclear added value of SFT use	Added value is unclear
Lack of access to live demonstrations of SFT use with neutral contact	Lack of neutral advice

Experts' statements regarding barriers for farmers to adopt SFT, predominantly confirm the findings from the farmers' survey (see Table 4). Most frequently mentioned was the lack of access to SFT due to high investment costs for the most of the SFT and their associated systems. Moreover, experts also reiterated that another Europe-wide barrier to the widespread use of SFT is the lack of information about existing innovative technologies as well as individual and impartial advisory services for farmers. A Greek practitioner said: "First of all most of the growers, I mean, up to 99%, they´re not familiar with new technologies. And […] nobody until right now informed about new technologies (…) and what´s the benefits from that and at the beginning, the growers are very sceptical to adopt these technologies." These statements are therefore directly linked to SFT trialability – there is no opportunity to experiment with available SFT.

Experts confirmed findings from the farmer survey that access to SFT is a significant barrier to adoption. All experts stated that improving mobile infrastructure is crucial to SFT adoption and diffusion processes. The lack of a GPS correction signal (e.g. RTK) limits farmers when using automatic steering. Some countries enable farmers through national programs. The republic geodetic authority (EuroGeographics) in Serbia provides free GPS correction signals to farmers. However, in general, poor connection to broadband was stated as an infrastructural barrier to SFT adoption, both by farmers and by experts from research, practice, and industry, and from across Europe.

A contested barrier to SFT adoption is how society views agriculture and the resulting pressure on farmers to produce food at a low cost without damaging natural resources. Farmers largely agreed that technology in general can support farmers' recognition of work by the public (see above). At the same time, experts added that the societal attitude towards environmental conservation would further support SFT adoption, although the public views farm mechanization as contradictory to the romantic view of agriculture that educational institutions convey. A German research expert stated that the "public view on agriculture is completely different. It starts already in school, children look at books, very romantic description of agriculture in these books. […] I see a contradiction of the behaviour of the citizens, or urban people, they have this romantic view of agriculture and how food is produced." A practice expert from the Netherlands added that media shows a distorted image of agriculture which also leads to a misunderstanding and misconceive of SFT: "Then I think the consumer has a problem with milking robots on organic farms. It´s not an issue fortunately, but there could be that type of tensions from the consumer perspective due to the lack of know-how of the consumer."

Supportive factors for adoption: social actors and sources of information

General results from our survey show that farmers rated (1) private advice (independent from any company) (61% of farmers), (2) other farmers (59% of farmers), and (3) agri-tech providers (56% of farmers) as the most important sources of information regarding SFT. The least important source of information for farmers were public extension (33% of farmers) and banks (14% of farmers).

There were country-specific differences between the information sources preferred by farmers. In particular, private advice was ranked as less important in Serbia and Spain than in the Netherlands and the UK. Agri-tech providers were rated as more important information providers in Germany and the Netherlands than in Greece and France. There was no significant difference between countries, cropping systems, or farm size classes in regard to the importance of other farmers as sources of information regarding SFT (Fig. 4), indicating that across all countries, cropping systems, and farm sizes, other farmers were equally important.

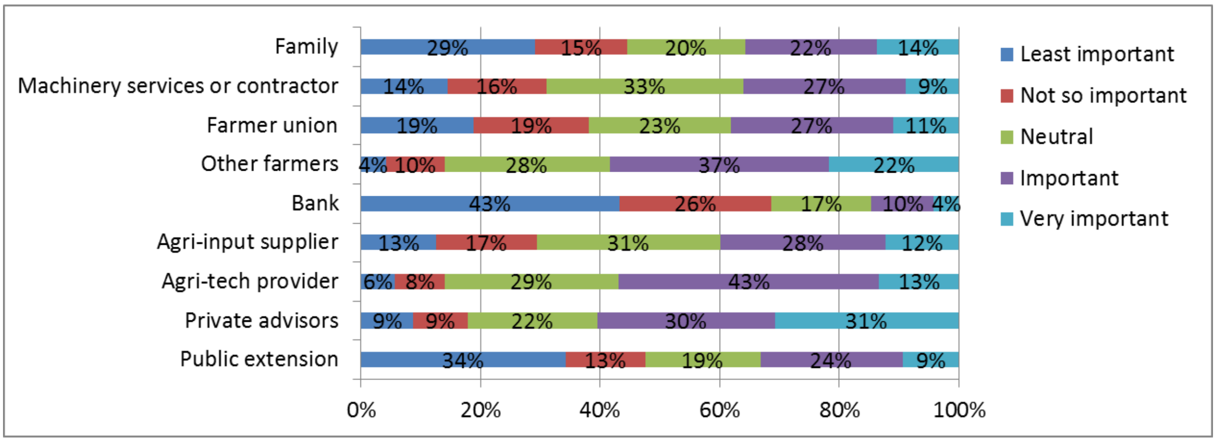

Figure 3 The importance of different information sources regarding SFT for farmers.

Where farmers look for information is diverse. Given a range of information sources that farmers consult regarding SFT, 31% of the farmers relied on professional literature and 27% relied on information they got when attending trade fairs. Professional literature (i.e. agricultural magazines) may be in support of searching for independent advice, and trade fairs may be a place to network with other farmers and independently inform themselves about what is available. Social media was another important source of information (13% of farmers).

Expert interviews confirmed the findings from the farmer survey that trustworthy advice by independent sources, i.e. peers, advisory, or extension services is, and would be, very important. Experts stress the fact that advice and information that is impartial and independent from companies is important to farmers, and the farmers' community is therefore the first choice information source. For example, an expert from Greece noted the importance of other farmers (e.g. neighbours) for information regarding SFT: "…in Greece, and I think, in most of the European countries, the farmers are working by seeing what their neighbours are doing. … even if they are searching the internet about this, it´s not so easy to buy something if they´re not sure that it will work for them." This quote shows that other farmers are an important source of information, but also for the observability and the trialability of SFT. Similarly, another Greek expert also noted the value of informal information exchange between farmers at local village cafes after a day in the field. A Dutch farmer noted "When [information on SFT] comes from within the farmer community the amount of trust will be higher, because [it is not attached] to big commercial [enterprises] that after your money." An expert in research from Germany noted that in the farmer community there is mistrust in company-based information, and that farmers want an independent advisory service or even an extension service that can provide information about particular SFT or technological features that are not disseminated throughout particular regions. Nevertheless, some experts noted that developers and providers of technology play an increasingly decisive role for the dissemination of innovative technologies (e.g. SFT) precisely because of the decline of state advisory organizations – as observed the important role of agri-tech providers for information about SFT. There was a unanimous opinion among experts that in the decision-making process regarding SFT use or adoption, the social environment surrounding the farmer, i.e. the peer-to-peer or farmer-to-farmer communication, was one of the most decisive factors. There were single statements made regarding concrete information sources, i.e. workshops, press media, internet and the local community, that were context specific. Apart from that, representatives of all expert groups perceived a deficient quantity of decent, fair-minded advisory services as a huge issue almost all over Europe and an insufficient information (flow) and communication about new technologies in all regions.

Discussion

As suggested in previous literature (see Burton, 2014), we found no trend in the demographics of the surveyed farmers, besides that the larger their farm, the more likely it was for them to rely on SFT for farming. Survey and interviews confirm that farm size, cropping system, are both somewhat correlated with pedo-climatic regions, and economic size (i.e. tree crops in smaller sized farms, arable crops in larger farms), and together these factors are most relevant in influencing whether or not farmers adopt SFT. Contrary to what the interviewed experts assumed, we found no effect of age or education on whether or not farmers were adopters or had sought out information on SFT. However, non-adopters farmers sought out information on SFT more than adopters, even though the majority of farmers that we surveyed had sought out information on SFT. This, combined with the high expectations that all farmers have of SFT suggest that the interest and mental readiness for SFT is available.

Results from both the farmer survey and interviews highlight a consensus regarding a subjectively perceived advantage of using technology in farming. Considering SFT characteristics, farmers largely agreed that these technologies are useful, and are better than what was available before, particularly in regard to SFT ability to improve work comfort and processes, but contrary to experts' perception, farmers generally are not as strongly convinced that SFT can benefit the environment. Theory of planned behaviour (Ayzen, 1985) would suggest that a positive attitude regarding innovations is one of the important determinants of adoption. More specifically, the theory suggests that an individual's intention to behave in a certain way is the strongest predictor of that behaviour (in this case SFT adoption). Moreover, three main predictors influence an individual's intention: 1. attitude toward behaviour, 2. social pressure that others have on the individual, and 3. the individual's perception of how easy or difficult a certain behaviour may be. In our study, we found that farmers have a positive attitude toward SFT adoption, but that the social pressure could greatly depend on the farmer-to-farmer communication and the specific farming context in terms of farming system and farm structures. We also found that there is an overall idea by farmers that technology can improve farmers' public image (survey), which could be related to less environmental pollution generated by newer technologies (expert interviews), so several of the predictors for adoption behaviour would be fulfilled. However, how easy or difficult it is to adopt SFT is potentially defined by the access to SFT that each individual farmer has, so that the situational component of the innovation process should not be underestimated (Pino et al., 2017; Albrecht 1963).

Communication channels are essential for individuals to create and share information, and connect two individuals, potentially one who has adopted the innovation (or knows a lot about it) and one that has not adopted the innovation (or does not know a lot about it) (Rogers, 1995, p.18). This suggests that individuals rely on a subjective evaluation of an innovation as it is presented by others, rendering the adoption process a social process. Our findings highlight that farmer-to-farmer communication could catalyse positive or negative attitudes regarding SFT, since farmer-to-farmer communication is based on the trialability, observability, relative advantage of SFT. These channels could play a more important role than the inconsistent advice (according to experts) that farmers receive on both appropriate technology, and on how to use certain technologies to maximize the relative advantage they may have. This was also found in Wales, where poor advice to farmers restricted entrepreneurial activity on farms (Morris et al., 2017). So while some of the certain communication channels could support innovation adoption among the European farming communities, there are still barriers due to ineffective communication channels and information transfer.

Despite the heterogeneity among the farmers' contexts and experts' backgrounds, both groups similarly assessed barriers to innovation adoption. We found that barriers to SFT adoption can largely be divided into 2 general categories, one that is more structural, related to access, be it via cost (initial investment or repairs), information (about available SFT or advice on how to use SFT), or infrastructure (broadband, satellite). The other category of barriers that we identified was technology-related. Findings from both the survey and the interviews also suggest that structural barriers differ between countries or regions in Europe, with a divide between north-west Europe (Germany, the Netherlands, and the UK) and southern Europe (Greece, Serbia, and Spain). This divide not only reflects differences in infrastructural conditions (European Commission, 2017*)* but also the different access modalities due to a pluralism of advisory service providers (Knierim et al. 2017). Therefore, farmer-to-farmer communication channels may be the most consistent source of information for farmers across Europe, and steer the way barriers are dealt with.

Conclusion

In the context of the EU Horizon 2020 project "Smart-AKIS", which assesses end-user's needs and identifies factors affecting innovation adoption and diffusion, we surveyed a sampling of farmers that represent the heterogeneity of agricultural contexts in Europe, and interviewed a diverse group of experts. There was a general agreement regarding supporting factors for SFT adoption, namely farmers' motivation and positive attitude towards SFT, with high expectations for SFT to improve work processes and comfort. Access was a major barrier, either due to lack of broadband, high costs, or appropriate information –for both gaining access to SFT or for obtaining help to better use SFT and gain added value. There was a north-west and south Europe divide in information sources identified as important, except for other farmers. Communication channels and sources of information can in this sense be a supporting factor for SFT adoption, or can reduce adoption if appropriate information is missing. Specifically, this means an information system that is neutral and can support farmers in obtaining information on solutions (in this case, SFT) that correspond to local, regional contexts. Such a system would complement the informal farmer-to-farmer communication that plays a large role in supporting innovation adoption and dissemination.

Acknowledgments

We are grateful to all of our interview partners for sharing their thoughts and opinions with us. This research was generously funded by the EU Horizon2020 funding program, project number 696294.

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