Deliverable 2.3:

Report on factors affecting innovation, adoption and diffusion processes

Müncheberg, April 2017

Document Summary

Deliverable Title: Report on factors affecting innovation, adoption and diffusion processes

Version: 1

Deliverable Lead: ZALF

Related Work package: 2

Author(s): Borges, Friederike; Kernecker, Maria; Knierim, Andrea; Wurbs, Angelika

Contributor(s): Claudia Trouillier

Reviewer(s): Thanos Balafoutis, Spyros Fountas

Communication level:
- **PU Public**
- PP Restricted to other programme participants (including the Commission Services)
- RE Restricted to a group specified by the consortium (including the Commission Services)
- CO Confidential, only for members of the consortium (including the Commission Services)

Grant Agreement Number: 696294

Project name: SMART AKIS

Start date of Project: 1 March 2016

Duration: 30 months

Project coordinator: Agricultural University of Athens

Executive Summary

The European agriculture is subject to an ongoing process of technological progress and innovation and during the last 30 years the development of digital innovations in agriculture increased unlikely. Smart farming technologies (SFT), as a part of this digital evolution, are appraised to have an important effect on the development of a sustainable European agriculture and thus, their broad dissemination and adoption is considered as key for future competitiveness. In this context, the goal of this study was to identify socio-demographic, economic, political and societal factors that foster and/or hinder the innovation, adoption and diffusion processes of SFT. In total, we conducted 22 expert interviews in 9 countries (Denmark, France, Germany, Greece, Italy, the Netherlands, Serbia, Spain). The interviewees belong to three different actor groups (research, industry, practice) with a comprehensive expertise on influencing factors along the process chain of innovation development, adoption and dissemination in the European context. To extract and analyse the information from the interviews the qualitative content analysis (QCA) with a deductive categorisation and coding method was utilized. Influences of farm and farmers' characteristics were unevenly rated by the experts, a finding that confirms the results of the smart-AKIS farm survey (Kernecker et. al 2016). Beyond these, the experts identified multiple additional aspects affecting the speed and direction of innovation implementation and development. Major dynamics mentioned are relating to economic and political strategies varying noteworthy throughout Europe. Differences can be mainly perceived between North-Western and South-Eastern Europe also reflected by societal demands and interests. The role of the European Union and its political decisions are considered essential for the future development of sustainable agriculture as supported by SFT. Most experts' opinions correspond on the increasing importance of SFT and their likely adoption by more and more farmers.

Table of Contents

Preface

This document constitutes Deliverable 2.3. It provides the conceptual design and methodology of the study, the guidelines used during the expert interviews and the results. The survey results are subsequently summarised and discussed according to socio-economic, political and societal factors affecting innovation, adoption and diffusion processes of Smart Farming Technologies (SFT).

1. Introduction and background

1.1 Introduction

The European agriculture is subject to an ongoing process of change and innovation. Since the industrial revolution in the 18th-19th century, mechanisation has become a crucial factor for production efficiency and competitiveness, with technical progress setting the tone in agriculture. The 20th century computer or digital revolution accelerated this trend, so that during the last 30 years the development of digital innovations in agriculture increased unlikely. In this regard technologies are not only directed to ease labour and increase production, but also to decrease the impact of farming on the environment at the same time. *Smart Farming* thus designates a cyber-physical system (Wolfert et al. 2017) connecting the entire farm management system and the value chain to a holistic concept of a modern agriculture facing the challenges of the 21st century (climate change, increasing world population, etc.).

However, it appears that the diffusion of these types of innovations is rather slow and does not occur homogeneously throughout the agricultural sector in Europe (Long et al. 2016). There are severe differences in speed and level of dispersion of state of the art solutions, referring to Smart Farming Technologies (SFT). Therefore, it is conducive to gain knowledge about the influencing factors that lead to differences in innovation, adoption and diffusion processes of SFT throughout Europe taking into account socio-demographic, economic, political and societal aspects besides farmers' practical perspectives. By consideration of specific actor groups (farmers, researchers, advisors, technology manufacturers) which are involved in the implementation and/or diffusion of SFT, it should be possible to detect discrepancies within the perception of the influencing factors and thereby reveal the gaps and/or misunderstandings that lead to obstacles in the innovation adoption and diffusion processes.

1.2 Literature review

The following literature review is to be understood as an extension to the literature review from deliverable 2.1, by the addition of the most recent publications mainly from 2016 and 2017.

The technological progress and in particular SFT, their development and adoption processes, are currently and highly discussed topic in politics, industry and the international research community. Wolfert et al. (2017) provide an extensive overview about the aims of technology development and the connected chances and possibilities but also fears, such as replacement of farmers' knowledge by technology, coming alongside with the digitalisation process. It is expected that SFT are going to play a key role when it comes to major future challenges in agriculture, such as the adjustment of operations to counteract to climate change and the increase of productivity to serve the growing food demand of an increasing world population (Long et al. 2016; Castle et al. 2016). There are manifold holistic approaches developed, which are supposed to collected data, analyse and visualize them to assist the decision making process, e.g. SmartFarmNet (Jayaraman et al. 2016).

It becomes obvious that the comprehensive adoption and implementation of these innovations is crucial for the attainment of the named goals. There are many conditional features discussed in the literature, among which is again the age of the farmer, the level of education and farm properties (Long et al. 2016). Castle et al. (2016) conclude that larger producers are also more likely to adopt

technology and that the age characteristic as an influencing factor has to be considered with their financial situation. Influences on farmers' decision making process by neighbours successfully implementing new technologies, so called spill over effects, are rated as a main driver for the adoption process (Tessema et al. 2016) and it is stated that it is possible to exploit and enhance this mechanism by introducing communities of practice (Dolinska & d'Aquino 2016). A similar impact can be observed with research, education and advisory services being a vantage point for distribution of SFT (Läpple et al. 2016). Due their survey in developing countries, Janvry et al. (2016) state that the highly influencing factors are the information about and availability of technology. Thornton et al. (2017) emphasize the importance of research, particularly the *"need to avoid the focus on outcomes being seen as disadvantageous to science, and development being seen as in competition with the science. Rather, they need to be seen as complementary, enabling, and ultimately liberating."*

Roberts et al. (2016) predict that the implementation of technology can support rural development. Furthermore, there is a potential perceived that measures for a sustainable agriculture will exceedingly include SFT, improve working conditions as well as security of farmers and their families, education and empower the cooperation in the decision making process regarding the development of rural areas (Bianco 2016). The same valuation of agricultural innovation processes and their potential impact on policy decision making is observed by Capalbo et al. (2016). There are already many national strategies developed to enhance the adoption and diffusion process to foster a sustainable and competitive agriculture also with the utilization of research within the process (Willets et al. 2013). A further requested process step indicated is the establishment of "*knowledge products*", which is the actual facilitation of output generated by SFT (Janssen et al. 2016; Antle et al. 2016; Jones et al. 2016; Capalbo et al. 2016).

1.3 Summary of findings from Task 2.2

In task 2.2, documented in the *Report on farmers' needs, innovative ideas and interests,* a total number of 271 farmers in 7 different European countries (France, Germany, Greece, Serbia, Spain, the Netherlands and the UK) had been interviewed to gather information related to perceptions of farming challenges, SFT potential, information sources for farmers, and adoption. Farmers of four cropping systems including arable crops, open field vegetables, orchards, and vineyards, have been selected to be interviewed (various farm sizes were taken into account). The main findings of the interviews can be summed up as follows:

- Perceptions of challenges: the challenges considered most important across the various national samples are to reduce crop diseases and to realise soil conservation. Reducing harvest losses was the challenge that was perceived as most important in Greece (89%) and Serbia (90%). Reducing water use was also ranked as highly important in Greece (61%) and Serbia (74%) and surprisingly perceived as less important in Spain (50%). Farm size seemed to matter as reducing water use was considered as more important on small farms <2 ha (77%) than on larger farms (> 100 ha).

- Perceptions of SFT as supportive to overcome challenges: high doubts were prevailing among the interviewees about the ability of SFT to help farmers overcome farming challenges. In all questions, between 51% and 63% of farmers were unsure about whether or not SFT could help overcome certain challenges.

- Information sources: interviewees mentioned private advice (independent from any company), other farmers, and agri-tech providers as the three most important sources of information. Almost 70% of the farmers recently sought out information specific to SFT.

Additionally, the main specifications of the different cropping systems as well as project ideas and needs were captured and could be condensed to the following points:

- GPS and similar devices (e.g. auto-steering) are mainly useful in arable crops.
- Agricultural apps were selected more by vineyard and orchard farmers.
- Weather stations and soil moisture sensors with automatic data upload are more valuable for orchards and vineyard farmers that rely on irrigation for better harvests.
- Drones, mapping, and aerial imagery are potentially more interesting for arable growers, as the images can help producers understand the large areas they have to manage.
- Three-fourths of the farmers said they experiment on their farms, and most frequently with equipment: e.g. building, adapting, and adjusting machinery to improve work processes; also testing of new technologies and cropping patterns which includes trying new varieties and crop rotations; cultivation: includes seeding, drilling, tillage, soil management and other management methods.
- More than half of the farmers provided suggestions for existing SFT to make them more acceptable or useful (e.g. improving SFT access, technological system as a whole, device level, data level, costs and compatibility).

The overall evaluation of the interviews and therefore the *farmers' needs, innovative ideas and interests* can be summarised as follows:

- **key improvements** proposed are related to **information outcome and its utilization** in the decision making process of the SFT already in use**, initial investment** and **flexibility and scope of application** of SFT due to its size.
- **most useful technology** to farmers included: **1) robots for monotonous work processes, 2) real-time diagnostics via drones, satellite imagery, or smart phone sensors, 3) (an improved) integration of various SFT**, and **4) data for information and decision support**.
- Specific findings across Europe: there are (1) differences in the **level of mechanization and technological orientation** related to the different farming structures and countries, (2) very different **Agricultural Knowledge, Information and Innovation Systems (AKIS)** can be observed in each of the countries, and (3) **farmer-to-farmer networks of information exchange seem to be the most consistent source of information** for farmers.

1.4 Goals & Objectives

The main purpose of this report is to complement farmers' statements and perceptions (as presented in Deliverable 2.2), with those of experts who work in the field of SFT development or are in other ways involved in agricultural technology progress and innovation processes, and hence have a good understanding of the larger societal environment that may impact innovation

development, adoption, and dissemination. Thereby we seek to reveal similarities and potential discrepancies between the perceptions of the factors by the targeted expert groups and eventually to detect misunderstanding and miscommunication within the named processes. Furthermore, we aim at gaining knowledge about the variances of socio-demographic, economic, political and societal influencing factors on the adoption of SFT across European countries and to provide a comprehensive view on challenges that agriculture and society are facing and how SFT may be a key to overcome these challenges.

This survey, together with task 2.1, will be guidance for the alignment of the thematic network, by pointing out the main aspects to focus on regarding the use of SFT, farmers' perceived needs and communication and information discontinuities and imminent challenges to be aware of.

Our main objectives are to identify:

(1) socio-demographic, economic, political and societal factors affecting the innovation, adoption and dissemination processes of SFT;
(2) perceived differences of these factors (1) throughout Europe and
(3) discrepancies between the perceptions of these factors (1) by the different expert groups.

2. Methodology and standards

2.1 Investigation method – Expert interviews

As a complement to the farm-level survey (Kernecker et al. 2016), the method of 'expert interviews' was selected to nominate and characterise factors that hinder and/or foster user acceptance of SFT. Experts were identified with the help of project partners' organisations and beyond. These qualitative investigations allow systematising and summarising the state of knowledge on influencing factors on national and international levels. Conducting expert interviews is a qualitative empirical research method, developed and well established in social sciences to explore widely shared and well established knowledge (Meuser & Nagel 2009).

2.2 Interview guideline

The list of questions was elaborated and utilized as a guideline throughout the expert interviews. Its structure in thematic sections aligns the factors affecting innovation adoption and diffusion processes and divides them into socio-demographic, economic, political and societal factors that foster and/or hinder the use of SFT. Furthermore, the guideline includes more comprehensive questions to set the thematic background, the European context and to explore future developments. The guideline is structured in sections as follows:

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.

f) political influence and strategies on the innovation and adoption of SFT.

During the interviews, the guideline was adapted onto the interviewees' background. Depending on the field of knowledge the questions were abstracted or concretized. The basic guideline is provided in the appendix (Appendix I).

2.3 Expert Groups

For the survey three different actor groups involved in agricultural technological progress and innovation processes were interviewed. To comprise all interest groups that are assumingly concerned with innovation adoption and diffusion processes, experts from research, industry and practice were contacted. Representatives from the expert group *research* are affiliated to universities, universities of applied science or research institutions. The group *industry* is represented by experts belonging to enterprises or business companies providing agricultural IT and machinery. Representatives from the expert group *practice* are affiliated to administration, journalism (with practical background) and agricultural associations.

Experts from the partner countries and beyond were chosen because of their known expertise and respectively to capture the European context of the research questions. Overall 22 interviews with experts from 9 European countries were conducted. The expert groups *Industry* (10) and *Research* (8) are represented twice as much as the practitioners' group (4). This different quantity of people in the expert groups was intended, as farmers were already comprehensively targeted for the elaboration of deliverable 2.2. The table below provides the distribution of experts per group and per country.

Table 1 Number of Experts interviewed in each country, in each expert group.

	Denmark	France	Germany	Greece	Netherlands	Serbia	UK	Inter-national	Total
Industry		1		2	4			3	10
Practice			1	1	1	1			4
Research	1	1	2	1	1	1	1		8
Total	1	2	3	4	6	2	1	3	**22**

The classification *International* contains two industry representatives from Italy and one from Spain. They are classified as international according to their reference frame during the interviews. A list of all expert interviewed, including their affiliation, is provided in the appendix (Appendix II).

2.4 Data collection and Data processing/preparation

The expert interviews were conducted face-to-face, via telephone or Skype. By utilization of a voice recorder it was possible to record the statements of the experts word-by-word which were transliterated using the f4transkript (Version 6.2.3 Pro) software. The transliterations of the

interviews were carried out following the simplified transliteration guidelines by Dresing & Pehl (2015), as we were interested in the content of the statements and there is no linguistic context of this research.

For the coding and categorisation in the course of the Qualitative Content Analyses (see 2.5 Data analyses) the MAXQDA (Version 10) software was utilized.

2.5 Data analyses

As the expert interviews are the main information and data source of this survey, the qualitative content analysis (QCA) was chosen as the analytical method. The QCA is a flexible method, which has to be focused on the specific research objective (Mayring 2010). The content-related structuring with deductive category assignment according to Mayring (2014) was the specific technique, which was utilized to extract the valuable information from the interviews. In Figure 1 the working steps of the named technique are presented and explained subsequently.

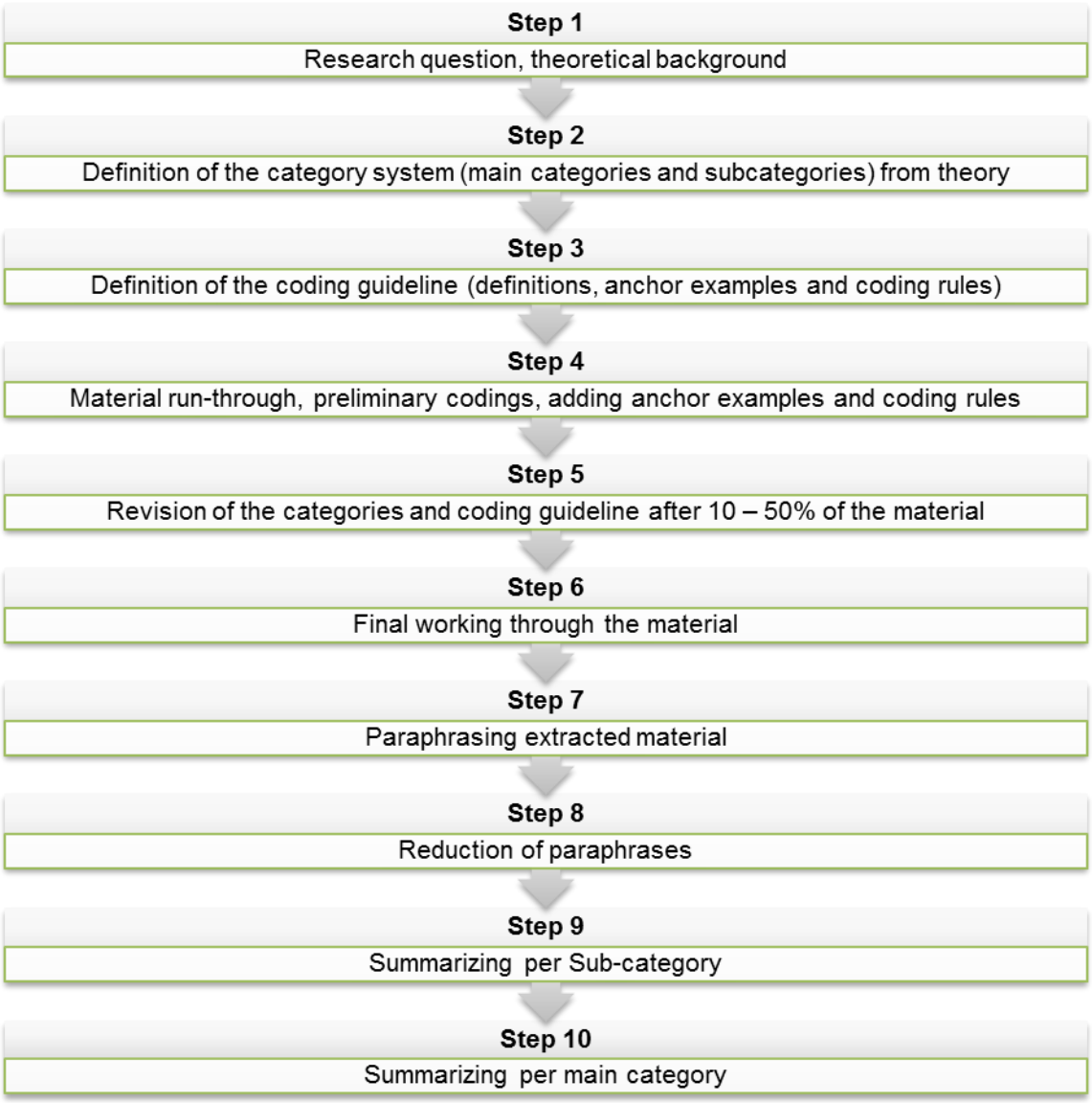

Figure 1: Steps of deductive category assignment and concretion (adapted from Mayring (2014)*)*

The determination of the research question and the theoretical background (Step 1) was deviated as described in the Goals & Objectives (see chapter 1.4). Step 2, describes the definition of the category system as derived from concepts and theories in line with the research question and the guideline of the expert interviews. Step 3 and 4 were combined as the coding scheme based on example coding cycles of two interviews. According to the description of Step 5, a revision of the categories and coding guideline were conducted after approximately 30% of the material was examined. The final categorisation and coding scheme is provided in the appendix (Appendix III). Subsequently, Step 6 was realized using the modified categorisation and coding scheme. Then, the codings (encoded text sections) were paraphrased (Step 7) and reduced (Step 8). In Step 9 and 10, the reduced statements or codings were summarized per sub-category and main category. The extracted results are presented in the following chapter (3. Results).

3. Results

The results of the expert interviews are subsequently summarized according to socio-demographic, economic, political and societal factors affecting innovation, adoption and diffusion processes of SFT. Additionally, the experts' vision of the future of agriculture and the aim of SFT development are presented.

3.1 Socio-demographic and economic factors

The factors affecting the adoption regarding farmers' socio-demographic and economic characteristics and the direct social environment of the farmer were more or less homogeneously mentioned across the three expert groups.

The personal attribute age is named crucial for the adoption rate of new technologies in all expert groups as well as across European countries. Older generations in the end of their working life tend to adjourn the technological equipment of the farm to the next generation and it is assumed, that associated with this alternation of generations, the adoption will eventuate happen incidentally. Though, age is not a constraining indicator for interest in new technologies. The education level is also named as crucial but the designation levels are targeting two different types depending on the region. In Northern Europe, the further education towards innovative technology is indicated to be key for a positive attitude, while in Southern Europe a lack of general education is hindering adoption processes. Generally, it is confirmed, that farmers are interested in new technologies. In particular, a general interest was identified to increase the production either in quantity or quality, to decrease the amount of input (water, fertilizer, plant protection, etc.) due to costs or to ease labour. An easy-to-use approach and a distinct cost-benefit ratio are the main convincing arguments, when it comes to adoption of new technologies. In contrast, the interest in more environmental friendly or sustainable operation is a non-primary need and was mentioned as a welcomed side-effect of technology aligned to production.

Furthermore, it was generally agreed that the spill over effect, so the influence of successful adoption in the closer environment of the farmer, is decisive. On the other hand, the information about new technologies was described as insufficient in all regions. Representatives of all expert groups perceived a deficient quantity of decent, fair-minded advisory services as a huge issue almost all over Europe (further results in section 3.2 Political factors). Due to that, trustworthy

advice, from farmers' point of view, is not supposed to come from companies (chemical companies, machine companies, etc.), but from neutral, public advisory services. From an expert, it was stated, that the European farmers in comparison to farmers from the USA are more identifying themselves with their farms and products and are more willing to continue the long-established family business in the same manners as their ancestors.

As influencing features, according to the farm characteristics and infrastructure, the following properties were identified Europe-wide: The physical size of the farm on its own is not the deciding factor of the adoption rate; it always has to be considered together with the cropping system as the business volume is limiting, e.g. high value crops as flower bulbs (Netherlands), vineyards (Italy) or olive/fruit cultivation (Greece) on a small area. On the other hand, several experts in the practice group emphasise that economic farm size matters because of the possibility to make investments. Therefore, it is accurate to define the access to finance sources respectively the ability to deposit the initial investment for SFT as a conditional issue. Solvency, access to the market and the qualification for certification systems, are reasons, why farmers cooperate with others and are, as an association, more likely to adopt technology (e.g. to fulfil the regulations of the certification by traceability of product). However, size is limiting when it comes to the field or parcels due to the availability of adequate technology (further results in section 3.4). The lack of qualified labour is an actual problem which is supposed to be counteracted by the use of technology.

3.2 Political factors

The Common Agricultural Policy (CAP) of the EU has a huge impact on the development and adoption of SFT. The regulations towards a more sustainable agriculture influence the innovation and adoption process in order to comply with the legislation with the help of technology, as it is observed by all expert groups. Generally this is considered positively, however, the enforcement of the legislation is very negatively perceived by industry and practitioners and needs are expressed for adjustments. Experts from the industry group, state that the CAP provokes the opposite of the intended goals (strengthen agriculture and migration to rural areas) due to the current legislation and to subsidies. For instance, subsidies are hindering the innovative character of technologies because the award procedure is too complicated and slow (practice), if there are any available for the sake of innovation adoption. A frequently mentioned issue is the coordination and supervision of subsidies and how they are spent. Mainly in Southern Europe (Spain, Greece), the subsidies are not invested in modernisation or technological progress of the farm businesses, but it is used to finance the daily life due to the low income and the poor economic situation in general (crisis).

Experts from industry and research state that it is furthermore essential to supervise the implementation of publically subsidised SFT and the improvements achieved by them (tractor with SFT acquired because it is more affordable, but SFT features not utilized). Subsidies without specific stipulations are hindering the innovation process in the eyes of some experts from research, because the minimum income is guaranteed and there is no need to reassess and change on the farmers' side, while they are not encouraged to learn. One industry representative polemically summarised the perceived *EU* attitude*: "Well, I will pay the money. Are you happy? Ok. I`ll forget about you."* On the other side, there are also positive impacts of the CAP towards the innovation process: There are multiple EU funded projects all across Europe mentioned by all expert groups to support the development and adoption of SFT. Although Serbia is not a member country (candidate country) of the European Union it is incorporated in a variety of EU projects dealing with the promotion of SFT (e.g. IoF2020).

There are also strategies on the national level fostering the adoption of SFT. An example from Serbia shows that the public, free of charge provision of GPS correction signal promoted the adoption and implementation of GPS guidance and auto-steering immensely. However, the mere existence of measurements is not sufficient if the majority of the parties have no knowledge of it, which is far-reaching the case (promoting of SFT as a governmental duty). For almost all European countries, the experts depict a reduction of national advisory services, where they locate the capacities to inform the agricultural community about SFT. And they resume this reduction of public engagement as a decision with negative consequences for SFT dissemination in particular (as described in 3.1, the absence of fair-minded advisory services hinders the promotion of SFT).

Another issue is the public research funding towards innovation in the agricultural area, which were assessed differently. Differences occurred in the perception of how they are related to practice and in their accessibility. In The Netherlands for instance, farmers were mentioned as beneficiaries of a number of publically funded projects *"with trials […] where industry works together […] with farmers directly. And those projects aim to focus on openers and exchange of data, use of smart farming systems, explore the opportunities of smart farming developments and technologies"* (industry expert). Another interviewee stated that such projects are hard to receive. A research expert from Southern Europe stated that there is funding on national level to implement technology into governmental control mechanisms but not (known) regarding the implementation of SFT by farmers.

The overall strategies on rural development were mentioned as crucial for the future development of agriculture, and in this regard, the actual policies on rural development were evaluated critically by most experts. Especially for Southern Europe, governmental strategies for rural development were criticised by two experts: e.g. a general lack was perceived or bureaucracy as a hindering factor for implementation. A main concern is the availability of internet access across the whole country, as it is a basic requirement for many SFT: e. g. in the Netherlands, the missing mobile internet availability was pointed out as hindering the technology. Generally, there were rather rumours than evidence for targeted subsidies or political support of SFT among the experts: e.g. for Greece a national strategy to promote technology was mentioned but their successful implementation contested. More generally, one research expert questioned the role of the state with regard to formulate the technology development goal because a lack of skills is observed at the administrative level to recognize farmers' diversity and corresponding technological and non-technological innovations appropriately. Another expert was even referring to the European community in this regard and claimed that the technological (r)evolution is promoted and managed at that level.

3.3 Societal factors

The expert interviews indicate a change of view in society as a whole on environment and sustainability due to upcoming challenges as e.g. climate change, which leads to an increasing awareness of nature. In Europe, there are different degrees of this awareness or respectively different degrees of impacts of this awareness noticeable. The experts conclude that the general economic situation is dictating the priority setting. It was noticeable that the general interest in sustainability among farmers and within societies in general is lower in Southern Europe and higher in Northern Europe. Similarly, the societal view on agriculture is differentiated: in Northern Europe (e.g. France, the Netherlands, Germany) exists a broad range of expectations and a significant pressure from various societal groups on agriculture. It is stated that this is due to lack

of knowledge about agriculture and also wrong or obsolete images of agriculture communicated by public media and in education. There are examples as the implicit connection between a tractor on the field and the application of chemicals, in the heads of the public. Information, education, and elucidation in this regard are named critical for societal acceptance.

Another factor influencing the public appraisal of SFT is societies' rising demand for high quality, healthy food and the still increasing number of discounter offering also good and high quantity for a low price. In contrast these societal views weren't mentioned as relevant in the Southern European countries. In addition to the customer, the entire value chain actors (food processors, traders, retailers) demand traceability of the product regarding quality and origin. The variety of certification systems (e.g. GLOBALG.A.P) is a major factor fostering the adoption and implementation of SFT to fulfil the regulations and increase the value of the product. According to the experts this phenomenon was perceived all across Europe.

Although it has been stated that partnerships between practice, industry and/or research exist in all countries, this cooperation and its establishment could be significantly eased and simplified. There are still gaps in the mutual understanding and cooperation, and the most distinctive cleavage is between the research side towards industry and practice. Prejudices exist on both sides: On the one side, the intention of the research is allegedly aligned to raise funding for further research as well as publish papers instead of working on research topics in the step of actual practice. On the other side, the industry is denounced only to develop innovations due to the greed of gain. These prejudices are hindering the innovation development and thereby adoption and dissemination.

Developers' interests were described as oriented towards farmers' needs as they are the customer of the products. It was stated that new technology is always based on customer requests. Furthermore, a number of reasons for the lack of technologies for small parcelled farms became obvious. At first the technology for small farms (mainly suggested to be robotics) are too disruptive to the developer company business model (research); secondly, there is no investment from smaller farms in development due to the mentioned reason of scarcely available funds (industry), and third and very basic, there is still a lack of knowledge how to support smaller farms with technology with bearable and realistic acquisition costs (industry).

3.4 Future of agriculture and aim of technology

The expert groups predict a general trend towards technology and smart farming in the future of European agriculture. However, single experts are sceptical about this development and what the consequences will be for different interest groups. They are expecting a loss of knowledge with increasing automation and see the risk that farmers' experience is neglected. One research expert was summarising it bluntly: *"Good farmers need good tools, rough tools, and robust things. They don't need whatever sensors."* Equally a practice expert emphasized farmers' experience as crucial for taking the right production decision: "*I think for a computer automated systems it is very hard to detect the right thing to do, because it's a lot of feeling and experience."*

The anticipated development comprehends a further intensification, the minimization of inputs and a maximization/optimization of output by single plant processing ('intelligently targeted inputs', research). The next step will be the establishment of data environments around the technology of individual farms and the connection via networks to streamline the data transfer and optimize the utilization of the output of all data automatically collected by smart soft- and hardware. Therefore, the industry proclaims that it is necessary for the European community to manage this evolution. A

concern mentioned primarily in this regard is the data ownership and is described as *"the next battle"* by a research expert. A reverse track-and-trace approach will foster sustainability on the long-run. The approach lays open where the product a consumer is buying comes from and enables him to support sustainability directly, but also disclose the history of the field by a continuous documentation of operation and processes executed on that field (value of the field).

The economy of size will become obsolete as a result of the drift towards autonomous machines and robotics with a more flexible scope of application. Single research experts are convinced that this drift will also promote the ecological and landscape diversity by the possibility to reintroduce landscape elements (e.g. single trees or ponds in the middle of a field will be identified by optical sensors). Practice experts would like the technology by its flexibility to preserve the diversity of European agriculture for the future *"because it enriches the culture and society*".

The lack of qualified labour is considered to become even more critical in the future. Mentioned reasons were the general migration trend from the rural to the urban areas and also impacts of specific developments and events in the EU (e.g. Brexit), referred to by research experts. Additionally, a research expert stated that it is crucial to *"attract the next generation of farmers – the human capital*" through the development of rurality. Experts of all groups are convinced that the technology development is going to have an explicit impact on the work and the profile of farmers. It will change to farm management and the supervision of machinery instead of actual work on the field and thereby also ease of work. The next generation of farmers will automatically or naturally adopt SFT as they are "*sons of the internet*" (industry).

4. Conclusion

Generally, the expert interviews tend to confirm the results of the farmers' interviews, especially with regard to farm-level influencing factors. Additional gain can be drawn from the broader view that many interviewees revealed, the cross-country comparisons and the anticipating reflections shared.

So, at the farm level, we find that the role of information provided by peers, and by (public) advisory services, is highly ranked. Equally, education is considered as a fostering factor and here, a difference between North-Western and South-Eastern Europe is made: while in Southern Europe a generally weak education level is considered hindering the SFT adoption, there is specific further education and non-formal training in Northern Europe which are conducive if attended by farmers.

Another cross-cutting finding is that small-scale farmers tend to be neglected by SFT developers; not only because there is limited financial power assumed, but also because of more sophisticated challenges that e.g. constitute small parcels of land. On the other hand, experts also see an important potential in SFT to support future diversified and small-scale farming with robotics and other labour-saving technologies.

As a critical fact, the research-practice cooperation is considered insufficient and also barriers between industry and (public) research are perceived. Such hesitant attitudes are not favourable to the development of innovative solutions.

Across Europe, the weak role of agricultural advisory services, especially of public ones, is deplored because a higher need is felt of informing farmers fairly about advantages and

opportunities of SFT. But not only advisory services, even the larger agricultural knowledge, information and innovation systems seem to be not enough pro-active in informing about and creating awareness of SFT. Hence, agriculture-related images that prevail in the public might still rather create a negative connotation between technologies and e.g. environmental impacts ('spraying pesticides') than transmitting the chances that are related with SFT.

A number of experts were quite critical with regard to the impacts of the EU policies. Especially direct payments and subsidies were seen as making farmers comfortable with the given situation and preventing learning and proactive search for challenges. Also, rural development policies weren't considered specifically favourable with regard to SFT. On the other hand, the increasing number of EU–level projects on innovation and technologies was positively appreciated.

With regard to the near future, experts were convinced of the increasing importance of SFT and their likely adoption by more and more farmers. Most experts emphasised the advantages of such developments more than inconveniences while two interviewees also strengthened the risks as e.g. farmers' alienation of natural resources and traditional practices and the question of data privacy and protection.

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THIS PROJECT HAS RECEIVED FUNDING FROM THE **EUROPEAN UNION'S HORIZON 2020 RESEARCH AND INNOVATION PROGRAMME** UNDER GRANT AGREEMENT N. 696294

SMART AKIS PARTNERS:

ΓΕΩΠΟΝΙΚΟ ΠΑΝΕΠΙΣΤΗΜΙΟ ΑΘΗΝΩΝ
AGRICULTURAL UNIVERSITY OF ATHENS

REPUBLIC OF SERBIA
AUTONOMOUS PROVINCE OF VOJVODINA
PROVINCIAL SECRETARIAT FOR AGRICULTURE, WATER MANAGEMENT AND FORESTRY

WAGENINGEN UR
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Delphy

zalf

OLG

BioSense

INTIA
Tecnologías e Infraestructuras Agroalimentarias

CEMA
European Agricultural Machinery

ACTA
les Instituts Techniques Agricoles

David Tinker & Associates Ltd
EurAgEng

Appendix I

Smart-AKIS Interview Guide:

- Introduction, ask about responsibilities and competences
- Clarify the data use: ethics statement
- Smart-AKIS deals with the development, adoption, and dissemination of smart farming technologies (SFT) and digitalized technological innovations in agriculture. In this particular part of the study, we are specifically interested in how societal norms and values shape and guide the development and diffusion of innovations in this field. This means that we are focusing on the farm-level, social-system level (the immediate social network that farms are a part of), and the societal dimensions (cultural values and norms in different groups) that influence decision-making processes regarding SFT. As such, our objective is to gain a comprehensive understanding of economic, social, and political factors that shape the development, adoption, and dissemination of SFT.

- ***What is your vision of agriculture in the future, particularly regarding the role of SFT?***
    - More specifically, looking at the current situation and into the future, what are the main challenges facing European agriculture?
        - What is the role of SFT in overcoming these challenges?
    - Can you speak more to how SFT are key to a more productive European agriculture? Why?
    - Can you speak more to how SFT are key to a more environmentally sustainable agricultural production? Why?
    - How do you think SFT play a role in social and economic dynamics on farms or rural areas?

- ***How would you describe the aims of innovation in agriculture in general?***
    - Are technical innovations in agriculture promoted for easing labour, or for replacing labour?
        - How does that influence the future of farms and rural areas throughout Europe?
    - Are other innovation needs, besides technological ones, taken into account by developers or decision makers within the agricultural knowledge system?
    - Where do you see the greatest need for technological and SFT innovation for agriculture?

- ***How would you describe the driving forces behind agricultural innovations and technological developments?***
    - How would you describe the role of farmers (their needs, values, interests) in the direction of technological innovations?
    - How would you describe the role of specialized businesses or branches (e.g. subcontractors) in shaping the development of technological innovations?
    - Are there gaps between theory and practice or between farmers and developers, and if so, where are they and why?

- ***How do societal values and norms shape and guide the development of innovations in general?***
    - How do society's values or interests play a role in the development of SFT innovations or the process of their adoption?
    - How do shifts in societal values shape farmers' demand for innovations? (E.g. urban citizens looking for more organic, regional products that embody more than food production, or the importance of low cost food and the associated discount groceries)

- ***Not all innovations are equally fitting for all potential adopters. Are there SFT or technological innovations that are relevant and attainable for all farmers in all contexts?***
    - How would you describe the farmers and types of farms that are targeted with technological innovations?
    - How do you see this situation in (your country) compared to other EU countries? Or what about (your sector) compared to other sectors?
    - There are many reasons why certain farmers do not adopt certain SFT. Can you speak to the innovation processes in agriculture for non-adopters?

- ***What is the role of research and advisory services in promoting certain innovations amongst farmers?***
    - How do research and advisory services compare to family and neighbour-level information sources?

- ***How would describe the role of subsidies, policies, or regulations in directing the adoption and dissemination of innovations?***

- ***How would you define the individual factors that motivate farmers' adoption of SFT (personal factors or farm-specific factors, such as cropping system, size, life-stage of farms)?***

Appendix II

Experts interviewed	Organization/Institute
Guerric Ballu	CEO of Exel Industries of Agrifac Machinery
Prof. Dr. Simon Blackmore	Harper Adams University, Head of Robotic Agriculture
Borislav Brunet	Provincial Secretariat of Agriculture, Water and Forestry (APV) (Project Partner 9) Senior Associate II Application of geo-information technologies and systems in agriculture
Dr. Marianne Cerf	INRA-SAD, French National Institute for Agricultural Research
Prof. Dr. Eike Dobers	University of applied Science Neubrandenburg, Crop farming
Dr. Kyriakos Drivas	University of Piraeus, Department of Economics, PhD Agricultural economist
Prof. Dr. Hans Griepentrog	University Hohenheim; Process engineering in plant production
Geert Hermans	ZLTO (Southern Agriculture and horticulture Organization), Innovation consultant
Dr. Panagiotis Ilias	R&D Director of Neuropublic - IT in Agriculture
Mark Legas	President of Pegasus Agrifood Coop (7Grapes Producers Organisation) - Food Scientist B.Sc., M.Sc., CQA. -Farmer
Saša Marjanović	PhD candidate at the Faculty of Technical Sciences, University of Novi Sad
Antonio Mazia	CNH Industrial, Vice president of Precision Solutions & Telematics
Leon Noordam	Chairman H-WodKa® precision agriculture project, arable farmer
Krijn Poppe	University Wageningen, Business developer
Massimo Ribaldone	SDF Group; Executive R&D Director
Ignacio Ruiz	Secretary General of ANSEMAT, Spanish association of Ag machinery manufacturers
Prof. Dr. Claus Sørensen	Aarhus University
Zisis Tsiropoulos	CEO of AGENSO, Company for Smart Farming Technologies
Peter van der Vlugt	CTO at Kverneland Group (Netherlands / Europe) & Chairman of AEF (Agricultural Industry Electronics Foundation)
Paul van Ham	MultiToolTrac - Co-founder
Aaldrik Venhuizen	Manager R&D plant at Agrifirm
Niklas Wawrzyniak	Executive and editor Bioland Verlag

Appendix III

Matrix of categorisation and coding scheme:

Interview-Target:	*Understand factors affecting the innovation development, (non-) adoption, and dissemination of SFT*		
Structural Dimension	**Categories**	**Sub-categories**	**Definition of categories:** *Sub-category ___ (Category ___) contains all information regarding*
Socio-Economical Factors	Farmers Characteristics/ Behaviour	Background	age, education and history of the farmer ((non-) and adopter).
		Interests	the interest of farmers within innovations (e.g. technical, environmental, productivity).
		Self-perception	the farmers' self-perception (e.g. job or profession; traditional farmer or business manager).
	Information System	Advisory	the prevailing organized advisory service (e.g. public/private advisory services, extension services, farmers association).
		Information Source	the information systems used mainly by the farmer and what is supposedly the strongest influencing factor affecting the decision making process (e.g. internet; other farmers; family; scientific papers; magazines).
		Education	further qualifications, training or workshops, cooperation with research or company.
	Farm properties	Farm characteristics	size & cropping system, field site conditions & slope, etc.
		Farm Infrastructure	labour availability, logistics, market access, profitability having influence on decision.
Political Factors	Payments	Subsidies	if subsidies are available (national / international), how they are organized (award procedure) as well as the control mechanisms referring consumption and compliance of the subsidies.
		Public Research funding	public research fundings having influence on innovation process.
	National Strategies	Economical/ ecological campaigns	national strategies having influence on the innovation process (e.g. green revolution, IoT, agriculture 4.0).
		Rural areas	the strategies on supporting the development of the rural areas.
Societal Factors	Research	Ecological concerns	demand of sustainable agriculture and responsible resource handling (water, air, soil quality; biodiversity).
		Value chain	demand of transparency, responsibility, quality and price of food, control mechanisms (consumer, food industry).
	Public	Contradiction within farm industry	the shift of agriculture to agroeconomy (Acceptance of innovations, specialised technology, environmental treatment).
		Developers interest	the interest of developers (machine developers, chemical industry).
General	Future of Agriculture		challenges and how to overcome them and how SFT can be key to a more productive and sustainable agriculture.
	Aim of technology development		the general trend of innovation development (ease or replace labour, need for technological and/or other innovations).
	Differentiation within Europe		differentiation of situation in country discussed to European standard (or other countries in the world).