

Deliverable 2.2: Report on farmers' needs, innovative ideas and interests



Document Summary

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Executive Summary

Agricultural and rural regions in Europe face a number of economic (e.g. farm income), social (e.g. abandonment), and environmental (e.g. soil degradation, biodiversity loss) challenges. Smart farming technologies (SFT) are one option that may support farmers in overcoming these challenges. SFT include farm information management systems, precision agriculture technologies, and agriculture automation and robotics. Given the development of SFT, it is particularly interesting to explore how they play a role - or not - in supporting farmers' and their farms. Therefore, the goal of this study was to understand farmers' technological needs and interests regarding farming and SFT throughout the EU. We conducted surveys with farmers in France, Germany, Greece, Spain, Serbia, the Netherlands, and the UK. Farmers were selected according to their cropping system (arable crops, open field vegetables, tree fruits, and vineyards) and farm size class (<2, 2-10, 11-50, 51-100, 101-200, 201-500, >500 ha), for a total of 271 farmers. Surveys were conducted from the beginning of August to late November, and gathered information related to perceptions of farming challenges, SFT potential, information sources for farmers, and adoption. A combination of multiple choice questions, Likert-scale data, and open-ended questions provided insight to subjective perceptions of SFT, how they may help overcome challenges in agriculture, information sources that are important for farmers, and how some of the patterns differ between adopters and non-adopters. Summary statistics in the R environment were used for analysis. While farmers' perception of challenges in agriculture was shaped largely by country-specific contexts, there was an overarching tendency amongst farmers to be uncertain about the ability of SFT to help overcome those challenges. Interests and needs of farmers varied somewhat according to cropping system and farm size, but there was little difference between adopters and non-adopters. Farmers across countries and cropping systems indicate that they need more access to information about SFT, and that existing SFT is too costly and not compatible enough with other machinery.

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Preface

This document constitutes Deliverable 2.2. It provides 1) the methodology and standards (originally planned for Deliverable 2.1) used to evaluate farmers' needs and interests regarding Smart Farming Technologies (SFT), 2) the questionnaire used in all research hubs, and 3) the results. The survey results are subsequently summarized and discussed according to farm-level and farmer-level factors that influence the contexts in which SFT may be relevant across Europe.

1. Introduction and background

Agriculture and rural regions in Europe face a number of economic (e.g. farm income), social (e.g. lack of succession and subsequent farm abandonment), and environmental (e.g. soil degradation, biodiversity loss) challenges. Therefore, innovation in the agricultural sector is key to adapting to changes and transitioning to sustainable agriculture that benefits rural regions (van de Kerkhof and Wieczorek, 2005; Vogl *et al.*, 2015; Long *et al.*, 2016). There are multiple innovative approaches that can support farmers in dealing with the challenges they face, including institutional arrangements, educational programs, policies, and different combinations of technologies (Sayer and Cassman, 2013). Recent technological innovations for agriculture are diverse and encompass (1) managing spatial and temporal variability for stabilizing economic returns and reducing environmental impacts of farming through precision agriculture (Suprem *et al.*, 2013); (2) farm management information systems for collecting, processing, storing, and disseminating data to support farm operations and functions (Fountas *et al.*, 2015); and (3) using automated systems, robotics, and artificial intelligence at all levels of agricultural production (Zhang and Pierce, 2013) to improve the efficiency and environmental impact of agricultural systems. Together, these technological innovations can be described as “Smart Farming Technologies” (SFT). The contexts in which SFT may be effective in supporting farmers and their farms are likely to depend on a number of factors related to regional contexts, farms, farmers, and the technology itself.

While SFT are applauded for their potential to provide a solution for a productive and more environmentally friendly agriculture – particularly in the face of unprecedented climate and global change – they are not widespread throughout Europe. For example, in the USA, 20-80% of farmers use some kind of SFT, whereas in Europe this percentage is only 0-24% (Lawson *et al.*, 2011). Therefore, it is key to understand the different drivers and factors affecting the generation, adoption, and diffusion of agricultural innovations. Previous research shows that farmer demographics (e.g. age, education) play less of a role, than do their perception of farm, technology, and their attitudes. We hypothesized that by investigating farmers' perceptions of the challenges agriculture faces, how they perceive SFT being able to overcome those challenges, and who their information sources are, according to farm level factors, could provide insight to which SFT are relevant in distinct contexts throughout Europe. Here, we provide an overview of farmers' technological needs and attitudes in regard to farming and SFT that can ultimately help provide insight to factors contributing to or hindering SFT adoption and dissemination.

2. Methodology and standards

This section was originally meant to be included in Deliverable 2.1. Here, it serves the purpose to provide the rationale and aims for the purposeful stratification of farmer selection used in our study, in addition to the data collection process through farmer surveys.

2.1 Sampling rationale and background

Based on a literature review, we hypothesized that by using farm size as criteria for selecting farmers, a broad spectrum of farming realities could be investigated. This would allow us to investigate how available innovations, knowledge and innovation support systems, policy dynamics, environmental limitations, and social issues, all affected the divide between research and innovation. We hypothesized that broad heterogeneity among the surveyed farmers would include smaller subsistence farms, which may provide a critical role for rural populations (e.g. food security or economic stability in countries with small agricultural structures), and therefore may also provide useful insight to innovations that are relevant to them and their farms. Larger farms and farmers that are full-time have characteristically been associated with investments in SFT and more willing to experiment with innovations. Such farmers could provide insight to future SFT adoption trends relevant to sustainable intensification. In sum, appropriate farm size stratification aimed to reflect the trends in European agriculture and SFT adoption.

2.2 Sampling structure

Our study covered selected regions in 7 different European countries: France, Germany, Greece, Serbia, Spain, the Netherlands, and the United Kingdom. Four cropping systems were selected throughout all regions, including arable crops, open field vegetables, orchards, and vineyards (Table 1).

Table 1 Each regional hub and each of the 4 the cropping systems they address, according to grant agreement.

| Regional/national partner | Cropping systems |
|---------------------------|--|
| Greece | Arable, tree, open field vegetables |
| Netherlands | Arable, tree, open field vegetables |
| Germany | Arable |
| Western France | Arable, tree, open field vegetables, vineyards |
| East UK | Arable, open field vegetables |
| Serbia | Arable, tree |
| Northern Spain | Arable, open field vegetables, vineyards |

To help guide farmer selection, we allocated numbers of farmers to be selected based on each region, cropping system (Table 2), and farm size class (Table 3), in line with the national statistics related to relevant cropping systems (Tables 4-5).

Table 2 Approximate number of farmers interviewed in each regional hub, in each cropping system (based on Table 1).

| | 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 |

Table 3 Approximate number of farmers to be interviewed in each cropping system and in each size class, as appropriate (derived from Table 2).

| Approximate number of farmers | <2 ha | 2-10 ha | 11-50 ha | 51-100 ha | 101-500 ha | > 500 ha |
|-------------------------------|-------|---------|----------|-----------|------------|----------|
| 90 arable crops | 15 | 15 | 15 | 15 | 15 | 15 |
| 40 orchards | 5-10 | 5-10 | 5-10 | 5-10 | | |
| 50 open field vegetables | 5-10 | 5-10 | 5-10 | 5-10 | | |
| 20 vineyards | 5 | 5 | 5 | 5 | | |

Table 4 Agricultural holding by main type of farming (number of holdings) based on Euro Stat.

| Country | Farm category | % of total holding (UAA) |
|-------------|------------------------|--------------------------|
| France | Arable | 17 |
| | Vineyards | 14 |
| Germany | Open field vegetables | 12 |
| | Arable cropping | 12 |
| Greece | Olives (orchards) | 38 |
| | Open field vegetables | 10 |
| | Arable | 12 |
| Spain | Olives (orchards) | 21 |
| | Fruits | 16 |
| | Arable | 13 |
| Netherlands | Open field vegetables | 14 |
| UK | Open field vegetables | 18 |
| | Arable farming | 11 |
| Serbia* | Open field vegetables | 42 |
| | Vineyards and orchards | 12 |

*<http://www.arhiva.serbia.gov.rs/cms/view.php?id=1021%20%28accessed%20on%2030.08.10%29>

We categorized the total number of farmers that would be selected in each cropping system into size classes further adapted from Eurostat and FAO stat (< 2, 2-10, 11-50, 51-100, 101-200, 201-500 >500 ha). We adapted the size categories according to regional contexts that were deemed as more relevant. The goal for each region was to find approximately 5-15 farmers in the 7 most relevant size categories for the cropping system they focused, to achieve the most balanced design possible (Table 5). Further goals in farmer selection included representing adopters and non-adopters, male and female, and farmers from different age ranges as equally as possible.

If the prescribed sample selection could not be followed in each participating country, we suggested that the sampling should be organized in order to represent the size categories common in that country (Table 5).

Table 5 Farm size categories and the approximate % of total holdings that are in each size category adapted from Eurostat 2010

| | <2 ha | 2-10 ha | 11-50 ha | 51-100 ha | 101-500 ha | > 500 ha |
|--------------------|-------|---------|----------|-----------|------------|----------|
| France | 15 | 21 | 27 | 19 | 18 | |
| Germany | 5 | 20 | 46 | 17 | 11 | 1 |
| Greece | 52 | 37 | 10 | 1 | 0-1 | |
| Netherlands | 13 | 29 | 41 | 13 | 3 | 1 |
| Serbia* | 30 | 65 | 5 | | | |
| Spain | 27 | 38 | 22 | 5 | 5 | 3 |
| UK | 2 | 20 | 38 | 18 | 21 | 1 |

* Serbian data was retrieved from FAOSTAT

2.4 Questionnaire

The questionnaire was designed to gather information about the respondent, their farm business, and attitudes toward agriculture, innovations, and technologies (see Appendix 1). The survey relied on asking farmers to agree or disagree with statements representing different points of views (e.g. using the Likert Scale), asking simple questions with multiple-choice answers and a few open questions. Preferences regarding SFT were also captured using photo ranking, where 5 photographs of SFT types were presented that were representative of the most common and the most distant types of technologies dominating the SFT landscape (Fig. 4, Appendix 2).



Figure 1 SFT types addressed in the questionnaire. From left to right: Type 1, robots and autonomous machines; Type 2, drones and aerial imagery; Type 3, connected tools-climate-related data acquisition and automatic upload; Type 4, tractor GPS and connected tools, including controlled traffic farming and variable rate technology; Type 5, agricultural apps.

The questions included in the questionnaire were initially chosen based on hypotheses developed from a large base of literature (Appendix 3). The initial questions were expanded upon during the course of questionnaire development, and exchange with project partners to better reflect farming contexts. The questionnaire was divided into 3 main parts. It started general and became more specific in scope towards the end. The objective was to start with open and broad questions that did not threaten the farmer, but instead, engaged him or her. Potentially more sensitive questions, regarding the farmers themselves came later in the questionnaire. The first part had 22 questions, which were farm-related. The second part of the survey investigated farmers' knowledge, opinions, and attitudes regarding farming (e.g. challenges, information sources) and SFT (e.g. technology in

general). This section had 71 questions, but a part of it was divided into questions specific to adopters (16 questions) and non-adopters (11 questions). The last part of the survey had 36 questions related to farmers' socio-demographics (e.g. age, education), technological behaviour (e.g. mobile phone ownership, farm data documentation), values, and interests regarding farming. In this last section, open-ended questions recorded farmers' ideas about the kinds of SFT that would benefit or interest them. There were many questions that were asked in different ways a number of times to ensure we received consistent feedback that was controlled for. For example, we asked farmers both if they thought SFT were useful for farming, and if they thought technology was useful for farming. In total, there were 77 question "blocks" (with a total of 129 individual items), and the surveys lasted between 30 and 60 minutes, depending on how many questions were asked by the farmer or how much the interviewer had to explain.

There was a number of question "blocks" that were pivotal to capturing farmers' interests and needs:

1. Farmers' perceptions of challenges:

To start with a broad understanding of farmers' interests and needs regarding SFT, it seemed first most relevant to understand how they perceived key environmental and social challenges related to farming. In these items we listed challenges and had farmers rank them in their perceived importance to deal with. Such challenges included regulation compliance, reducing pollution, reducing inputs (fertilizer, herbicide, fungicide, insecticide), and improving impact on biodiversity.

2. Farmers' perceptions of SFT potential to deal with challenges

To understand how farmers' perceived SFT as being able to help them deal with the challenges they confronted, we asked them to rank the SFT "potential" in a number of items. These included broader ideas, such as "SFT are useful for farming" to narrower ideas, such as "SFT help reduce farm input costs." By analysing how farmers' perceive the potential of SFT to help them overcome certain challenges, we were able to get an idea of in which ways SFT need to be improved or adapted to become more relevant to farmers.

3. Farmers' information sources and information seeking behaviour

The direction of farmers' interests could reflect where they obtain their information from, and where they look for information, could provide an idea of the knowledge and innovation support systems in place in the farmers' environment.

4. Farmers' technological behaviour

To get an idea of farmers' tendencies regarding technology in general, we asked questions related to their data documentation and mobile phone use.

5. General technological needs

Farmers' general needs were captured via open questions. First, whether or not they experiment on their farms, and if they do, which types of experiments those may be. This provides insight to what needs to change on the farm, and how farmers approach those changes. Furthermore, open questions aimed to identify which improvements could be made to existing SFT, and which types of technologies would be most appropriate to them and their farm.

6. SFT types relevant to farms

Building on the previous questions, we sought to pinpoint which type of SFT would be most useful to each farmer interviewed, and how farmers would rank the main types of SFT according to importance. This exercise linked SFT types that would need to be further developed as appropriate to certain countries, regions (representative of key pedo-climatic conditions), cropping systems, and farm sizes.

7. Key differences and similarities between adopters and non-adopters

Questions specific to adopters and non-adopters focused on factors influencing decision-making prior to using or obtaining SFT.

2.5 Survey preparation workshop

In preparation for conducting surveys, a meeting was held in Berlin, on June 21, 2016, with 1-2 representatives from 5 of the 7 hubs (France, Germany, Greece, Serbia, the UK; see Fig. 2). Prior to the meeting, the methodology and standards, hypotheses, and questionnaire were developed at ZALF. All items were distributed to all participants to ensure that everyone agreed on all key points, and to make sure the documents were relevant to each regional hub. After receiving feedback and input from all participants, the documents were adapted and distributed amongst the partners once again as the working documents used for the workshop.

The goals of the workshop were to ensure that all objectives were agreed upon, to discuss any concerns for each region, to review the sampling stratification, to provide some theoretical background on survey methodology, to thoroughly review the questionnaire in detail, and to agree on a schedule. Methods presented were prepared according to Babbie (2015). Skype meetings with project partners from the remaining two hubs were held later the same week (Spain, the Netherlands). The questionnaire was subsequently updated.



Figure 2 Participants at survey preparation workshop, 5 out of 7 hubs were represented. From left to right: Camille Morel from FRCUMA Ouest (France), David Tinker from the European Society of Agricultural Engineers (UK), Milica Trajkovic from Biosense (Serbia), Julia Röhrig from DLG (Germany), Maria Kernecker from ZALF (Germany), Matina Voulgaraki from the Agricultural University of Athens (Greece), and not pictured, Stéphane Volant of FRCUMA Ouest. Skype meetings with Marcos Apesteguia Barberena of INTIA (Spain) and Harm Brinks of Delphy (Netherlands) were held later the same week.

The questionnaire was pre-tested with farmers in July 2016 in each region to test its appropriateness. Notes on sensitive, unclear, and unnecessary questions, survey structure, and length were taken into account and used to finalize the questionnaire. The final questionnaire was then redistributed amongst all partners, and a Google Form was created based on the final questionnaire to ease data entry.

2.6 Data collection

Contact to farmers was established through each regional project partner, based on the sampling guide presented below, using their established networks with farmers in their regions. To achieve the best possible distribution and avoid statistical redundancy, the aim was to select farmers with farms located in a variety of areas with different postal codes.

Project partners conducted face-to-face surveys or telephone interviews with farmers in each study region. Each of the interviewers was made aware of the importance of their role in the success of the survey. It was important that the interviewers stay neutral, since their presence in the data collection process should not have any effect on the responses given to questionnaire items. Interviewers helped build the questionnaire and therefore were familiar with it.

The survey was administered in written or electronic form, according to each interviewer's needs, and responses were transferred to a master excel file via the Google Form. Only project partners were allowed access to the form and spreadsheet. Each farmer was provided with an accompanying letter ensuring the anonymity of the data collected.

2.7 Data analysis

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 in the R environment (R Core Team, 2016).

The data was complete and had few missing values. Due to the standardized data entry method we used, the data was also of high quality. There were very few instances of non-response. There was no strong trend highlighting sensitive questions that farmers were unwilling to answer.

The data set (n= 271) was analysed using descriptive statistics to help portray trends of attitudes towards SFT and their adoption across countries, cropping systems, and farm sizes. Due to the complicated sampling structure and abundance of data, more detailed non-parametric cross-country and cropping system analyses (e.g. Kruskal-Wallis and Dunn-Nemenyi post-hoc test for pairwise comparisons due to unbalanced design) and multivariate analysis (factor analysis, generalized linear mixed modelling) will be used for a peer-reviewed paper, which will be submitted in 2017.

3. Survey results and discussion

3.1 Sampling stratification

Project partners in the 7 different European countries: France, Germany, Greece, Serbia, Spain, the Netherlands, and the United Kingdom conducted surveys with farmers based on the agreed-upon sampling stratification (see Methodology and Standards section). All four cropping systems were included accordingly, the numbers of farmers we aimed for in each of the cropping systems was reached, and in the case of vineyards, surpassed (Table 6).

Table 6 Number of farmers interviewed in each regional hub, in each cropping system (based on Table 1).

| | France | Germany | Greece | Serbia | Spain | Netherlands | UK | Total |
|------------------|--------|---------|--------|--------|-------|-------------|----|-------|
| Arable | 21 | 25 | 10 | 16 | 8 | 26 | 16 | 122 |
| Orchards | 0 | 0 | 27 | 10 | 0 | 9 | 0 | 46 |
| Field veg | 16 | 2 | 4 | 0 | 4 | 9 | 4 | 39 |
| Vineyards | 10 | 1 | 27 | 10 | 16 | 0 | 0 | 64 |
| Total | 47 | 28 | 68 | 36 | 28 | 44 | 20 | 271 |

The numbers of farmers surveyed in each of the size classes (< 2, 2-10, 11-50, 51-100, 101-200, 201-500 >500 ha) varied slightly from the sampling stratification, since each cropping system has a typical size range appropriate to the specific crop cultivation (Table 7).

Table 7 Numbers of farmers interviewed in each cropping system and in each size class.

| | <2 ha | 2-10 ha | 11-50 ha | 51-100 ha | 101-200 ha | 201-500 ha | > 500 ha |
|-------------------------|-------|---------|----------|-----------|------------|------------|----------|
| Arable (n=117) | 4 | 11 | 12 | 24 | 30 | 16 | 25 |
| Tree (n=46) | 8 | 27 | 11 | 0 | 0 | 0 | 0 |
| Field Veg (n=39) | 0 | 9 | 10 | 8 | 7 | 2 | 3 |
| Vineyards (n=64) | 1 | 35 | 23 | 2 | 3 | 0 | 0 |

As the sampling was done by the project partners, a bias towards organisationally related farmers can't be excluded. For example, in Germany, the surveys were conducted in large part by the German Agricultural Society (DLG), and so farmers who were contacted were mostly members of the organization, or attendees of DLG-organized events. While this method did not allow for representative samples within each country, cropping system, or farm size classes, it did enable us capture the technological needs, ideas, interests, and perceptions from a stratified farming population. Such purposeful sampling also affirmed *a priori* assumptions about the farming structure according to Eurostat and FAO stat. Due to large differences in relative sample size, cropping system, and size classes within each country, the country level grouping seems to best capture specific contexts.

3.2 Farm and farmer characteristics

The greatest number of respondents included in the survey came from arable farming (Fig. 3), which was surveyed in each of the 7 participating countries. The highest numbers of arable farmers included in the survey were in France, Germany, and the Netherlands, with farms mostly above 51-100 ha. The arable farming structure in those countries is markedly higher than the arable farming structure in Greece, and Serbia, where arable farms are generally smaller than 51-100 ha.

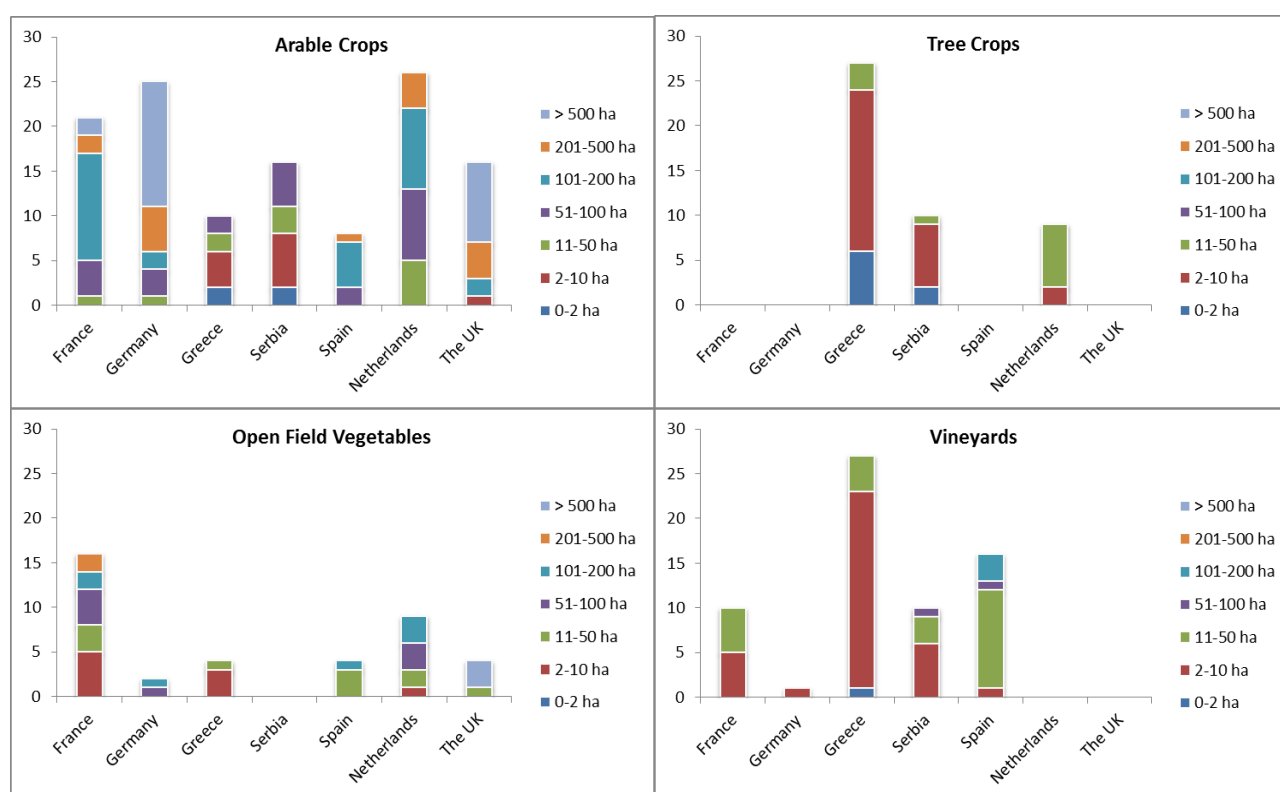


Figure 3 Farm size classes in each cropping system.

Farmers from open field vegetables were the smallest group included. The highest number surveyed came from France and the Netherlands. However, it is important to note that many Dutch arable farmers actually cultivate onions, carrots, and potatoes, but consider themselves arable farmers, so there could be some overlap between these categories in the Dutch case (personal communication). Orchards and vineyards were covered most predominantly in Greece, which correspond to their major crops (see Eurostat, 2010). Serbia and the Netherlands were the only other participating countries that conducted surveys on orchards. The number of vineyards in the survey came from countries traditionally associated with wine production: mostly France, Greece, Serbia, and Spain. Germany collected data from one wine farmer. The farm size in these latter two cropping systems are characteristically much smaller than arable and open field vegetables, and the farm size surveyed rarely surpassed 50 ha (see Fig. 3).

The sampled distribution of adopters in relation to non-adopters (Fig. 4) results in part from the fact that not in all cases this information was previously available. The proportions of adopter to non-adopter tend to reflect assumed national trends in the partner countries. In Serbia and Greece, adoption was relatively low, possibly due to limited access to SFT and appropriate infrastructure while adoption rates are higher in countries such as Germany, the Netherlands and the UK, where the agri-business is more active in technological developments. Moreover, a number of farmers from smaller farms stated that their farms were too small for currently available SFT and that SFT were too costly (Fig. 5).

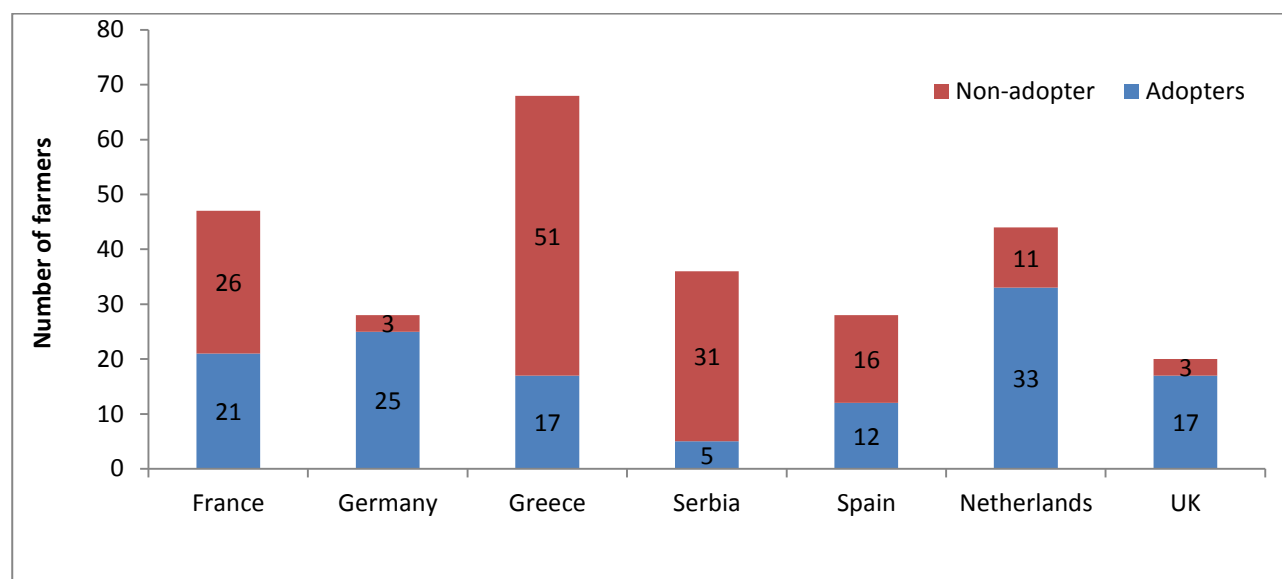


Figure 4 Total numbers of both SFT adopters and non-adopters interviewed in each country (total n=271).

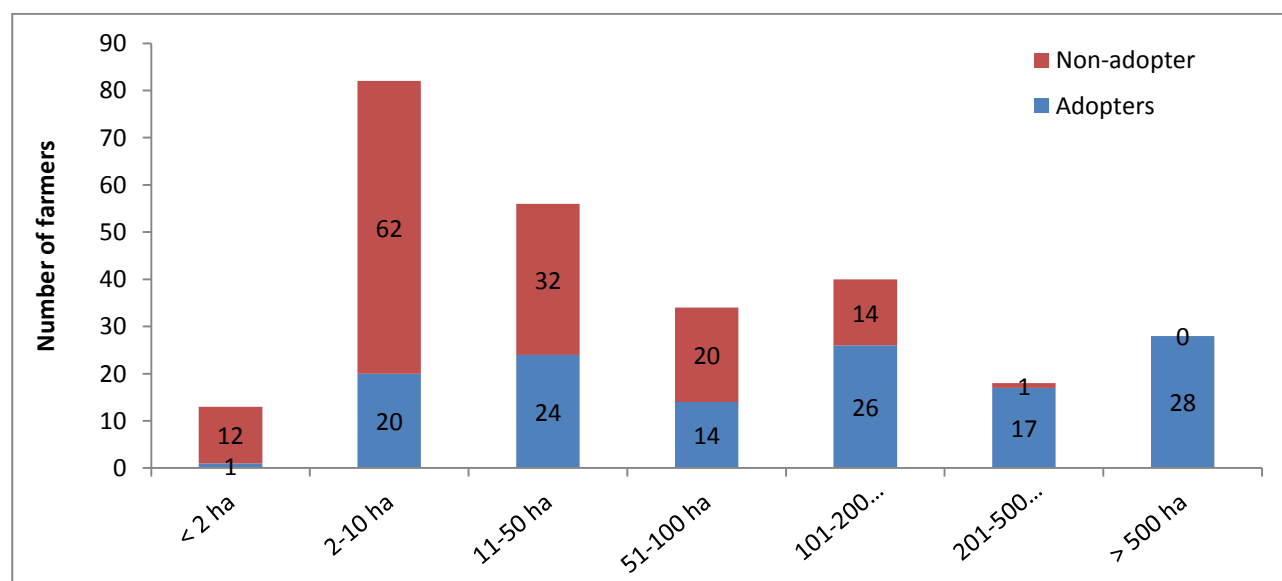


Figure 5 SFT adoption according to farm size.

In our sampling stratification, we also aimed to represent male and female farmers and farmers from different age groups as equally as possible. European farm managers are between 20 and 30%, and only in the age range > 65 years, do women account for over 30% of the farm managers (European Commission, 2013). In this survey, 92.6% of farmers interviewed were male. However, it has been documented that machinery and its maintenance is a typical male activity (Brandth and Haugen, 2010), which may have made it less interesting for female farmers to participate in our survey.

The trend in Europe is for the farming population to be aging – in 2007, there were 9 farmers older than 55 years old for each farm holder younger than 35 years (European Commission, 2012). This is reflected in the age range of farmers we surveyed (Fig. 6).

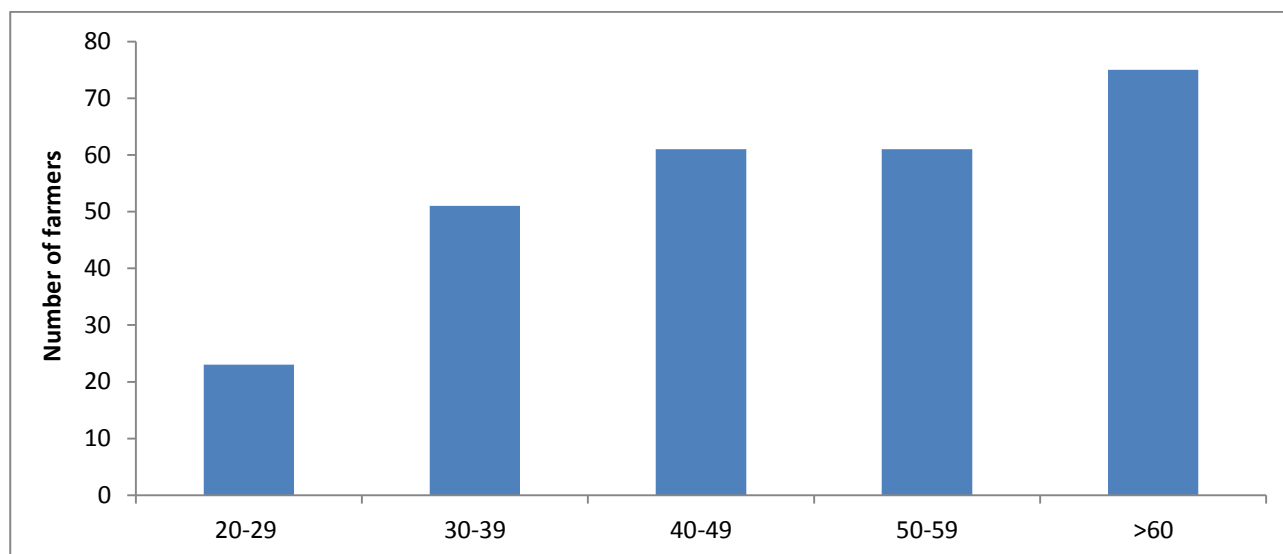


Figure 6 Numbers of farmers in each age category.

In general however, the stratification of farmers participating in the survey represented a wide range of ages. There were 2 farmers who were under 20 years old, but for the sake of analysis, these data were designated to the 20-29 category. Germany had the largest number of farmers between 20-29. Spain did not have any farmers in this age category. The largest amount of farmers over 60 were surveyed in England. Interestingly, given the heterogeneity of age structures between countries, when looking at age distribution within cropping systems, the proportions are relatively comparable (Fig. 7).

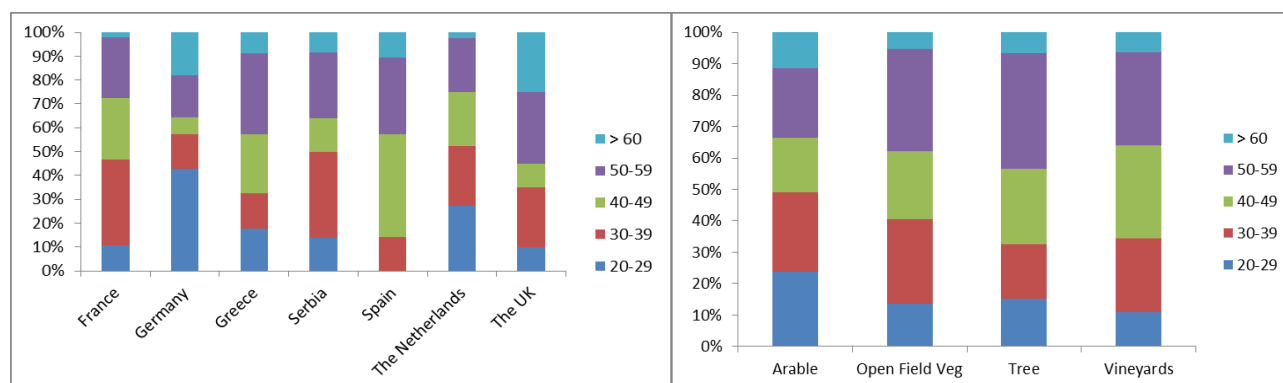


Figure 7 Age structure within each country (left) and cropping system (right).

3.1 Farmers' perceptions of challenges

We asked farmers to rank the importance of overcoming certain challenges in farming, which SFT could help overcome. Their responses can provide insight to the types of SFT they might need in each respective context. Across Europe, the most important challenge for 83% of farmers was to reduce crop disease while only 7% disagreed (Fig. 8). Similarly, 80% of farmers found soil conservation as important, and only 7% found it not important. In comparison, the least important challenge, in general, was categorized as reducing water use – 49% of the farmers said this was important, 24% were undecided or neutral, whereas 27% responded as saying this was not important. However, the pedo-climatic conditions in the south (Greece, Serbia, Spain) vary greatly from those in the north of Europe (Germany, Netherlands, UK, France). These strong differences in environmental conditions likely caused the low priority of reducing water in Europe as a whole. To investigate the differences in the perceptions of challenges, we looked at them according to different country, cropping system, and farm size.

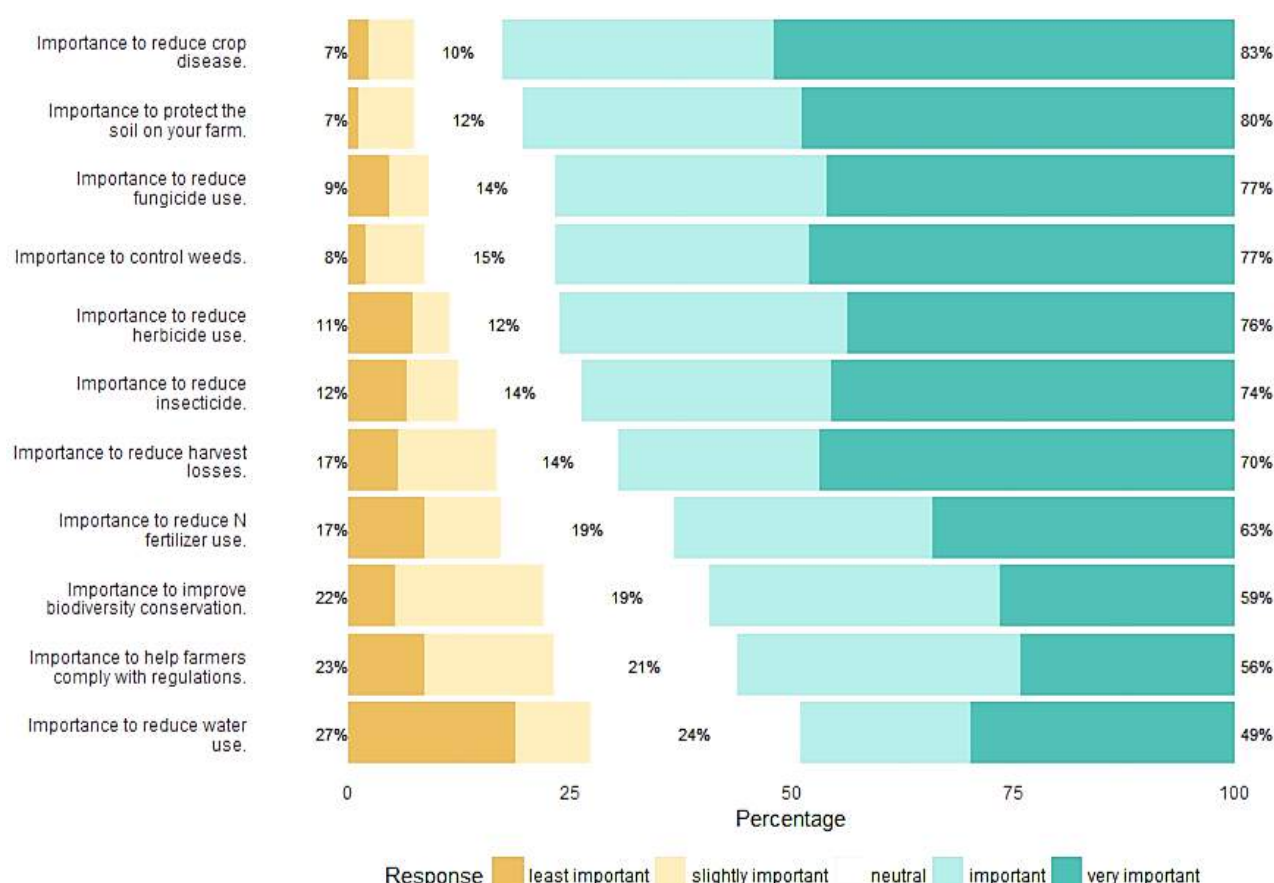


Figure 8 Farmers' perceptions of challenges in general, across Europe.

In several of the challenges listed, there were strong differences in perception between countries. The greatest differences between countries' perceptions of challenges were based on regulation compliance, biodiversity conservation, harvest losses, input use (herbicide, insecticide, and N fertilizer), and water use. In the UK, 90% of the farmers said helping farmers comply with regulations was important, and there were no farmers who disagreed. In Greece, only 34% agreed that this was important (Fig. 9). This could reflect the values that farmers place on compliance. Or, it could reflect the bureaucratic work associated with farm size – in the UK, most of the farmers surveyed came from large farms, whereas those in Greece came from smaller farms. Lastly, it could be related to the level to which technology already is incorporated into compliance measures.

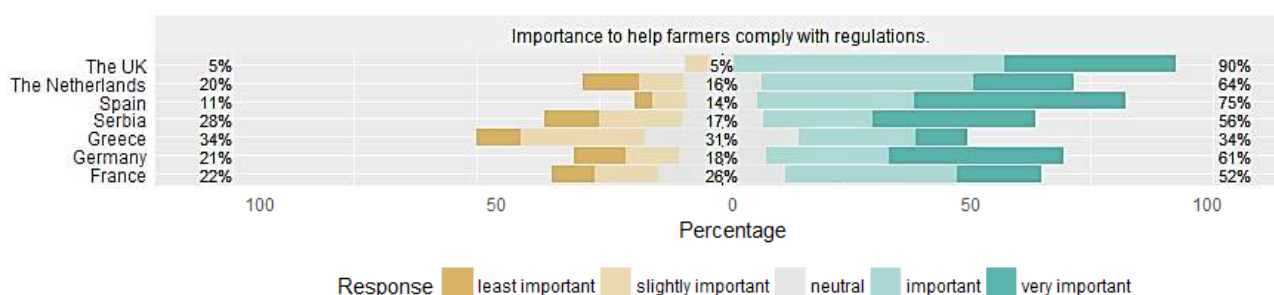


Figure 9 Farmers' ranking of the importance to comply with regulations according to country

In Serbia, 89% of the farmers found biodiversity conservation an important challenge that SFT should help them overcome. Only 6% disagreed. In the Netherlands, however, only 36% of farmers found biodiversity conservation an important challenge, and 39% found that this was not an important challenge (Fig. 10). This could be explained by the fact that biodiversity conservation has a high value in Serbia, and less so in the Netherlands. Or, it could be explained by the types of SFT that are common and in use in the Netherlands compared to Serbia, making biodiversity

conservation less of a concern. Furthermore, the Serbian farmers involved in the survey were in large part organic producers, who were very environmentally oriented (personal communication between project partners).

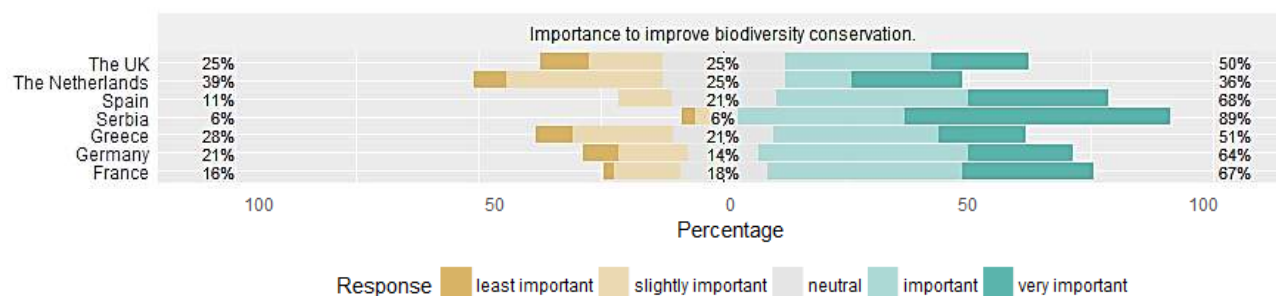


Figure 10 Farmers' ranking of the importance of improving biodiversity conservation of farms

Reducing harvest losses was the challenge that was perceived as most important to overcome in Greece and Serbia (with 89% and 90%, respectively) compared to other countries (Fig. 11). This could be explained due to the smaller farm structure in these countries, which corresponds to a higher relative value of the harvest per amount of land.

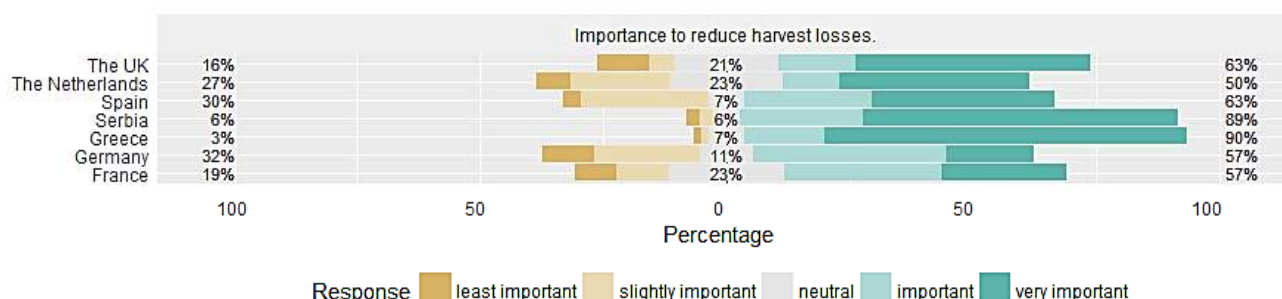


Figure 11 Farmers' perception of reducing harvest losses according to country

Reducing water use was also ranked as highly important to overcome in Greece and Serbia (perceived as such by 61% and 74% of respondents there, respectively), which could be related to climate and cropping system (Fig. 12). It was remarkable that in Spain, water use reduction was not a central challenge for farmers, given the low water availability. This could be an indicator that the challenge has already been addressed through available innovations, but this remains to be confirmed.

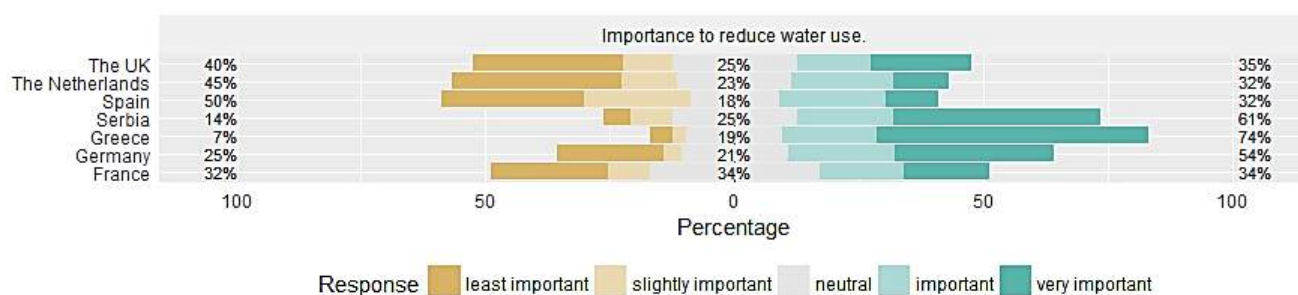


Figure 12 Farmers' perceptions of reducing water use, according to country

There were no marked differences in the results of the farmers' perceptions of challenges according to cropping system. The only exception was regarding farmers' perception of the importance of SFT to help farmers comply with regulations (Fig. 13). Here, 40% of orchard farmers did not find it important to use SFT to overcome regulation compliance, and only 38% found it important, whereas 56% of farmers from vineyards, 58% of open field vegetable farmers, and 62%

of arable farmers found it important. This result could be due to collinearity – most of the orchard farmers were interviewed in Greece. As such, when looking at country level differences in perceptions of challenges, Greek farmers found regulation compliance the least important (Fig. 12).

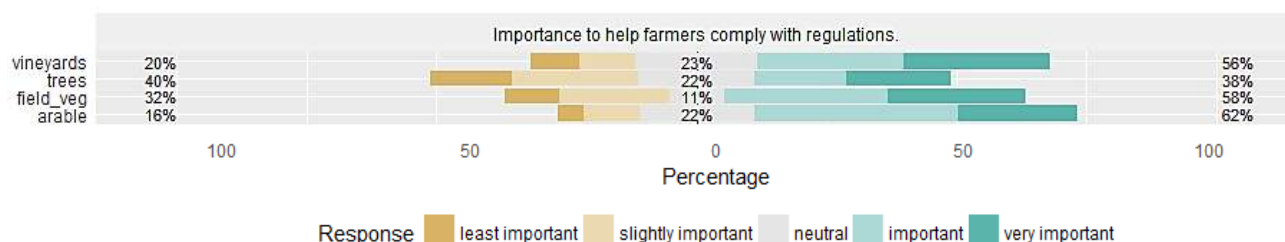


Figure 13 Farmers' perceptions of challenge of complying with regulations according to cropping system.

Variations in farm size may help explain some of the general differences observed in the perception of challenges facing farms and farmers. For example, the challenge of complying with regulations seems to grow with farm size (Fig. 14). As a farm grows, its role as a commercial enterprise and its footprint within the food system grows, making it more important to track compliance with regulations and certifications. On the other hand, the difference in perception of the importance to reduce water use was greatest for farmers from farms that were <2 ha (77% ranked it as important) and least important for larger farms (> 100 ha). Small farms were found mainly in the south (e.g. Greece), where irrigation is important. Another possibility is that larger farms may have already adopted SFT and therefore may have solved this problem, or it could coincide with the cropping system and country that is specific to the climates in those regions.

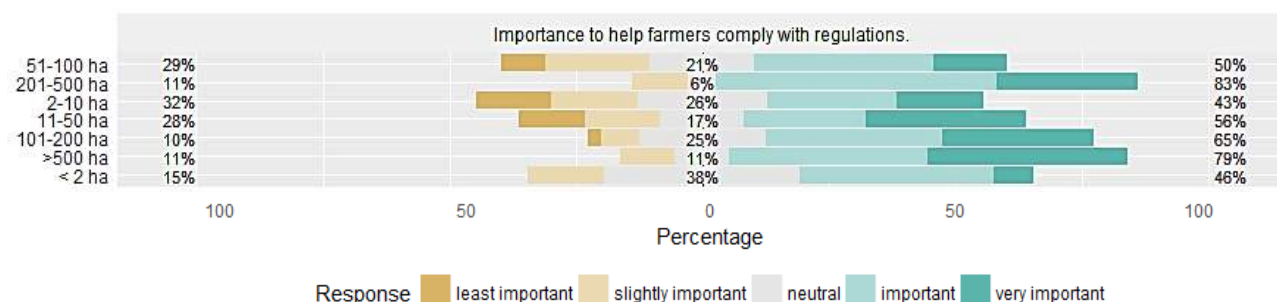


Figure 14 Farmers' perceptions of challenge of complying with regulations according to farm size.

Differences in farmers' age, education, or value variables did not appear to strongly affect differences in perception of how important it is to overcome certain farming challenges.

3.3 Farmers' perceptions of SFT potential

Farmers were also asked how they perceived the ability of SFT to help overcome certain challenges (Fig. 15). The points that farmers were asked to agree or disagree included whether or not SFT are "better than previous tools", "useful for farming", "decrease input costs", "help reduce pollution from farms", "improve farm income", "improve work comfort", "improve farmers' work processes or workload", "improve the impact of farms on nature", "increase productivity", and "provide information to help make better management decisions". Results indicate that there are high doubts about the ability to SFT to help farmers overcome farming challenges. In all questions, between 51% and 63% of farmers said they were unsure about whether or not SFT could help overcome certain challenges (Fig. 14).

Farmers most strongly agree with the statements "SFT are useful for farming" (46% of responses) and "SFT are better than previous tools" (36% of responses). These perceptions may reflect the expectations that farmers have of SFT. Farmers most strongly disagree with the statements "SFT improve farm income" (24% of responses) and "SFT improve impact of farms on nature" (32% of

responses). This indicates that the specific ideas of how SFT may be useful for farming or be better than previous tools are not entirely clear. As such, one important point to consider is that there is especially large uncertainty regarding the statement “SFT provide information to help make better management decisions”. The opinions are not only largely undecided, but also very split – 20% of the farmers do not agree, 53% are unsure, and only 27% agree. This highlights the need for data from SFT to become more useful to farmers, so that the potential can be clearly communicated.

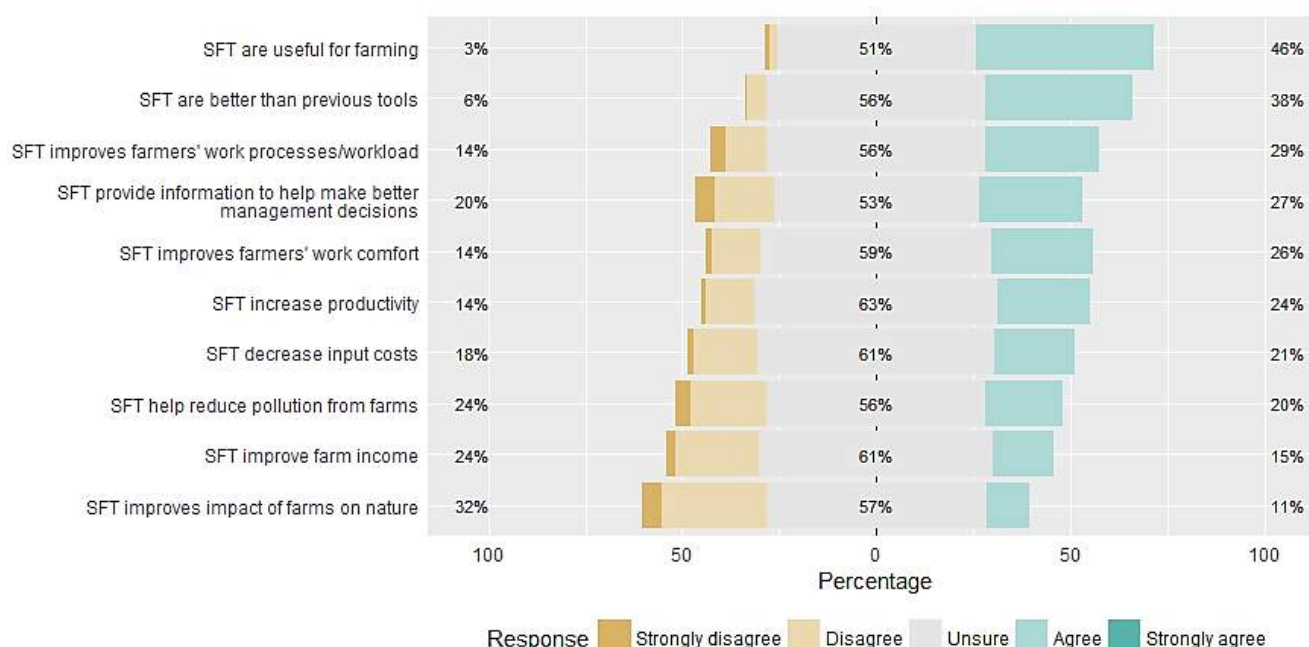


Figure 15 Perceptions of SFT potential

One of the most marked differences in the perceptions of the SFT potential to overcome on-farm challenges are related to SFT improving farm income (Fig. 16). In countries with the lowest adoption rates, there seems to be the highest perception that SFT increase income. For example, in Serbia, 97% of the farmers surveyed were non-adopters, yet 36% of them agreed that SFT could increase farm income, which was the highest rate of agreement. A similar trend was found among farmer responses from Greece. In the UK, on the other hand, only 15% of the farmers surveyed were non-adopters, and yet only 5% of all farmers agreed that SFT could improve income. Moreover, in Germany, only 11% of the respondents were non-adopters, and 24% of all of the farmers surveyed did not agree with SFT improving income. This highlights the gap between theory and practice, and the expectations non-adopters may place on new technologies for improving their situation.

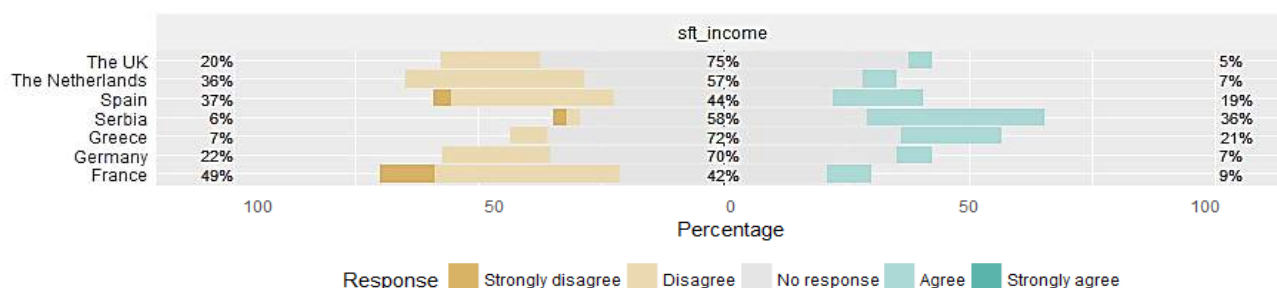


Figure 16 Farmers' perception of SFT potential for improving farm income, according to country.

Another interesting finding is that despite SFT adoption rates being in a similar range in the UK and Germany, 50% of farmers in the UK said that SFT improved work comfort, but only 14% of the farmers in Germany agreed with SFT improving work comfort (Fig. 17). This could potentially be explained by the age ranges of farmers surveyed in each of these countries. Over 40% of the

farmers surveyed in Germany were between 20 and 29 years old, which means that they cannot compare the current SFT to previous farming machinery, and about 30% of the farmers surveyed in the UK were over 60 years old, meaning that they could have been comparing SFT to previous tools.

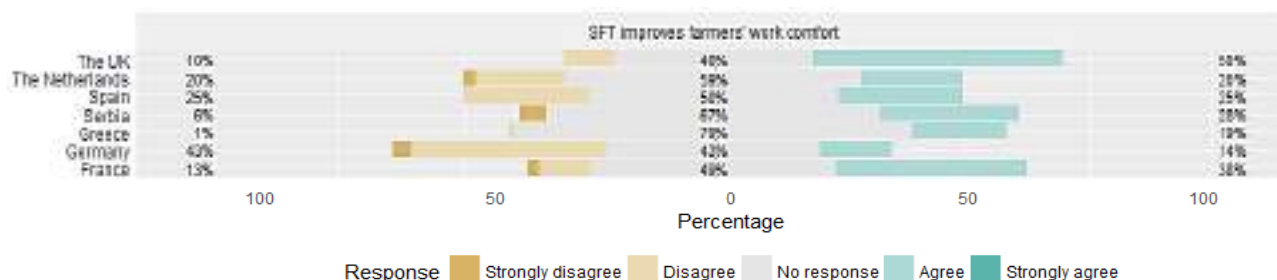


Figure 17 Farmers' perception of SFT potential to improve work comfort, according to country

At the cropping system level, there were a few key differences between farmers' perceptions of SFT potential. Wine farmers have the largest uncertainty about what SFT can do – 72% are unsure if SFT improve farmers' work comfort, 70% are unsure about SFT improving work processes, and 70% of wine farmers are unsure about whether or not SFT can increase productivity. Orchard farmers most strongly agree with the SFT potential to improve farm income and to provide information to help make better management decisions (Fig. 18). However, some of the patterns associated with orchards may be correlated with country-level SFT adoption effects. About 40% of the farmers surveyed in Greece and about 28% of farmers from Serbia are from orchards. These are the two countries with the lowest adoption rates, and so the farmers' perceptions may be most strongly related to expectations the farmers there have of SFT, without having the experience with the SFT themselves. This hypothesis is confirmed when looking at perceptions of SFT potential according to farm size. While uncertainty about SFT potential remains high even when accounting for farm size (ranges from 35% - 77% of the farmers responses), there are some very points with a clear opinion. For example, for farmers from farms >200 ha, 0% of the respondents disagreed with the statements regarding SFT being better than previous tools and that SFT are useful for farming. 36% farmers from farms >500 ha agreed that SFT decrease input costs, and only 4% disagree. These farmers were also almost exclusively SFT adopters, and thus were basing their opinion on experience.

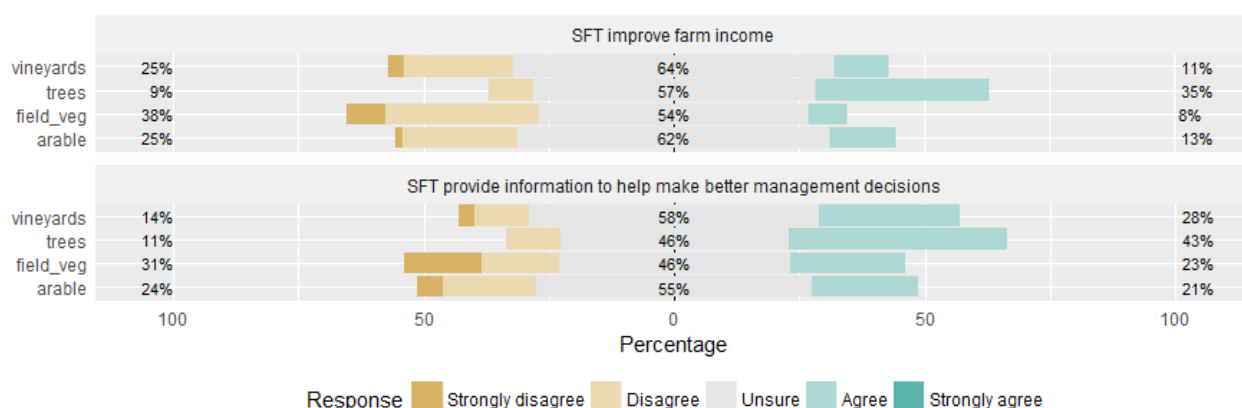


Figure 18 Farmers' perceptions of SFT potential to improve farm income (top) and to provide information to make better management decisions (bottom) according to cropping system.

3.3 Key information sources and information seeking behaviour

Across Europe, there are very different opinions about the information sources that play a role for farmers. Nevertheless, general results from our survey show that farmers rated private advice (independent from any company), other farmers, and agri-tech providers as the three most important sources of information. The least important source of information for farmers were public extension and banks (Fig. 19).

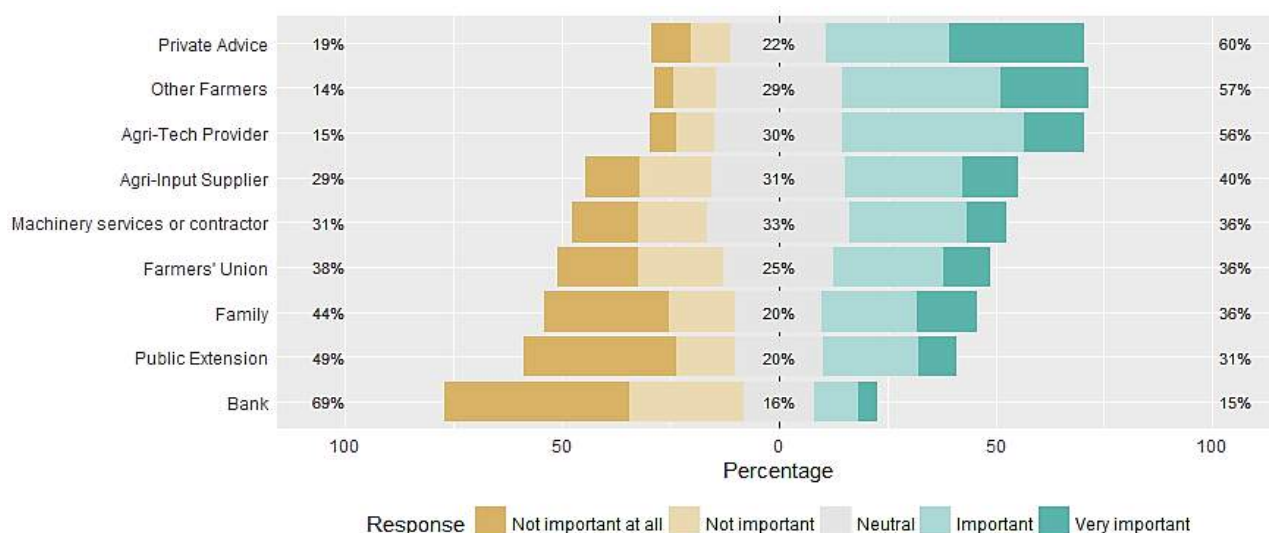


Figure 19 Farmers' rating of information sources in general.

Cross-country trends reflect heterogeneous Agricultural Knowledge and Information Systems (AKIS) in each country. There were 66% of farmers in the Netherlands and 61% of the farmers in Serbia who rated agri-input suppliers as important sources of information. In Germany, 79% of farmers, and in the Netherlands 77% of the farmers surveyed rated agri-tech providers as important sources of information. The largest undecidedness about agri-tech providers was in Greece, where 25% of the farmers rated them as not important, and 37% had an undecided rating of them. Similarly, Greek farmers rated machinery services or contractors as largely unimportant (51%). Family was rated as important by 67% of the surveyed farmers in Serbia, underlining a different farming structure than in the rest of Europe. The farmers' union was rated as important for both the UK (50%) and Serbia (58%). Private advice was most important for farmers in the UK (84%), the Netherlands (80%), and Germany (79%). Public extension was most important for Spain (57%), less important for Greece (81%) and Germany (75%).

Some of these differences may be further explained by differences in farm size. Farms that were 201-500 ha and >500 ha rated agri-tech providers as 78% and 75% important, respectively. Surveys done on farms >500 ha rated private advice as 81% important. Farms from all size classes rated other farmers as important (44-65%, Fig. 19). These differences may underline (1) differences in the level of mechanization and technological orientation related to the different farming structures and countries, (2) the very different AKIS in each of the countries, and (3) that farmer-to-farmer networks of information exchange may be the most consistent source of information for farmers across Europe (Fig. 20).

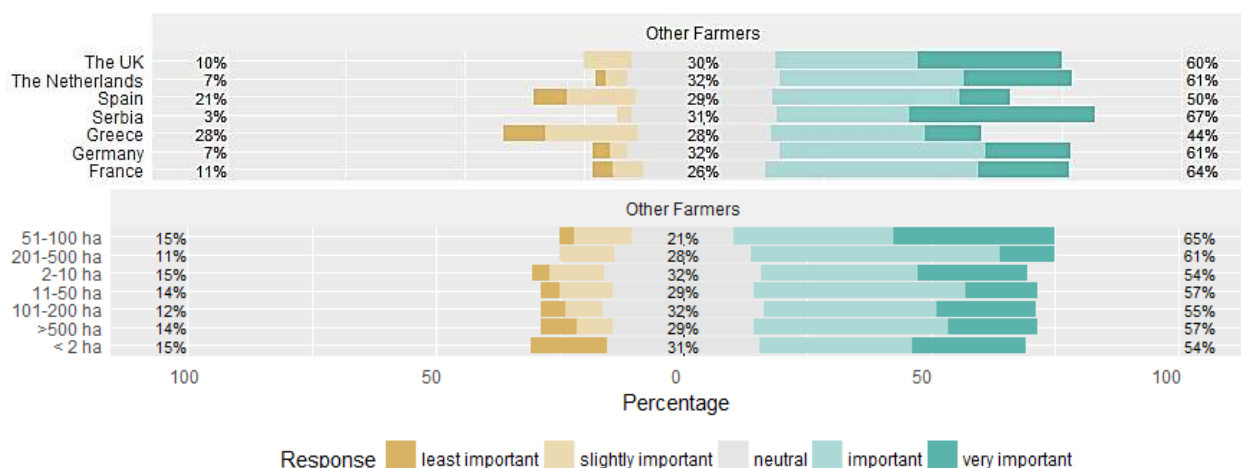


Figure 20 Relative importance of other farmers as an information source for farmers in different countries (top) and different farm size structures (bottom).

Regardless of which information sources play the more important roles, farmers largely stay informed regarding developments in agriculture. Out of the 271 farmers, only 3% (10) farmers never attended trade fairs (or similar), 16% (44) farmers visited trade fairs less than once a year, 30% (81) farmers visit trade fairs once year, and 50% (136) visited trade fairs more than once a year.

More than half of the farmers surveyed (67%) recently had sought out information specific to SFT (Fig. 21). Of those who had sought out such information, almost half (42%) were non-adopters. A third of the farmers had not recently sought out information specific to SFT. Although about 75% of these farmers were non-adopters, it shows that even SFT adopters did not feel the need to obtain new information on SFT (Fig. 20). These findings suggest that it is not a matter of being informed, but it may be more a matter of what is available and accessible.

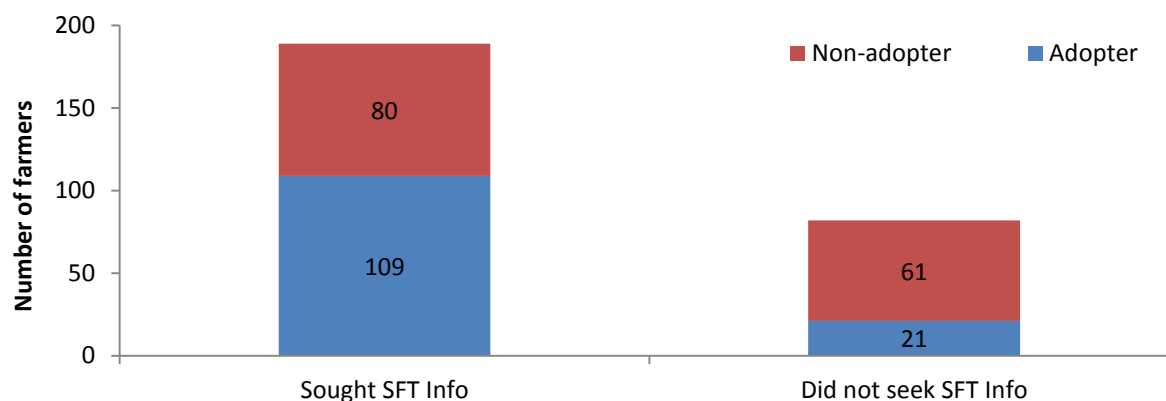


Figure 21 Number of farmers that sought out SFT-specific information according to adoption

Where farmers look for information is diverse (Fig. 22). Given a range of information sources that farmers consult regarding SFT, 31% (84) of the farmers relied on professional literature and 26.5% (72) relied on information they got when attending trade fairs. Social media (13%), workshops (8%), demonstration farms (6%), and advertisements (7%) also were important sources of information for farmers. There was no marked difference between adopters and non-adopters in the sources of information that farmers consult, except that non-adopters mentioned advertisements more frequently than adopters (Fig. 22).

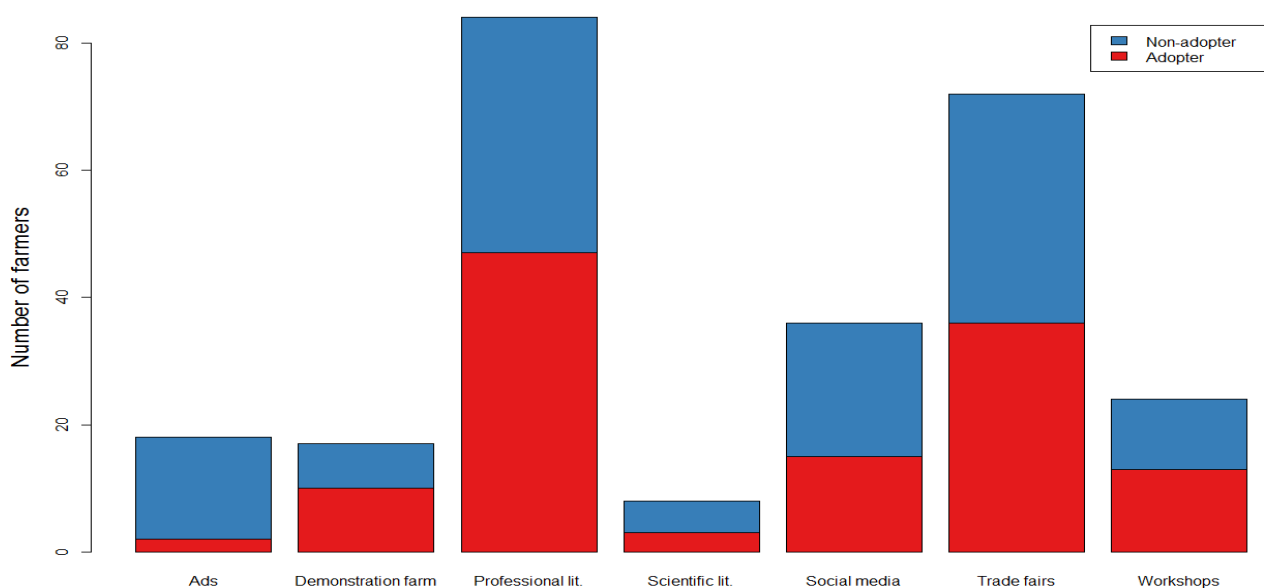


Figure 22 Most recent information used by farmers according related to SFT adoption. Responses that occurred <4 times were omitted from the figure to enhance visibility. Those responses included internet (n=3), agricultural research station (n=3), none (n=4), videos (n=1), and cooperative (n=1).

3.4 Technological behaviour

In previous studies, farmers' use of technology in their farming was also linked to whether or not they adopted technology (e.g. Kutter et al., 2011). In our study, we asked farmers if they recorded their farm data by hand, digitally, or both (Fig. 23). In all countries, farmers documented their data by using all 3 methods, except for in Serbia, where farmers document either by hand or a mix of hand and digitally. No farmers in Serbia exclusively documented their data digitally. In the Netherlands and the UK there was a larger proportion of farmers who documented their farm data solely digitally, and a correspondingly slim proportion of farmers who documented their data only by hand.

Time of mobile phone ownership also was significantly affected by country (Kruskal-Wallis chi-squared = 38.676, df = 25, p-value = 0.04) and cropping system (Kruskal-Wallis chi-squared = 41.34, df = 25, p-value = 0.02), but not by farm size. However, patterns in mobile phone ownership do not correspond to any other patterns related to SFT adoption observed in the study.

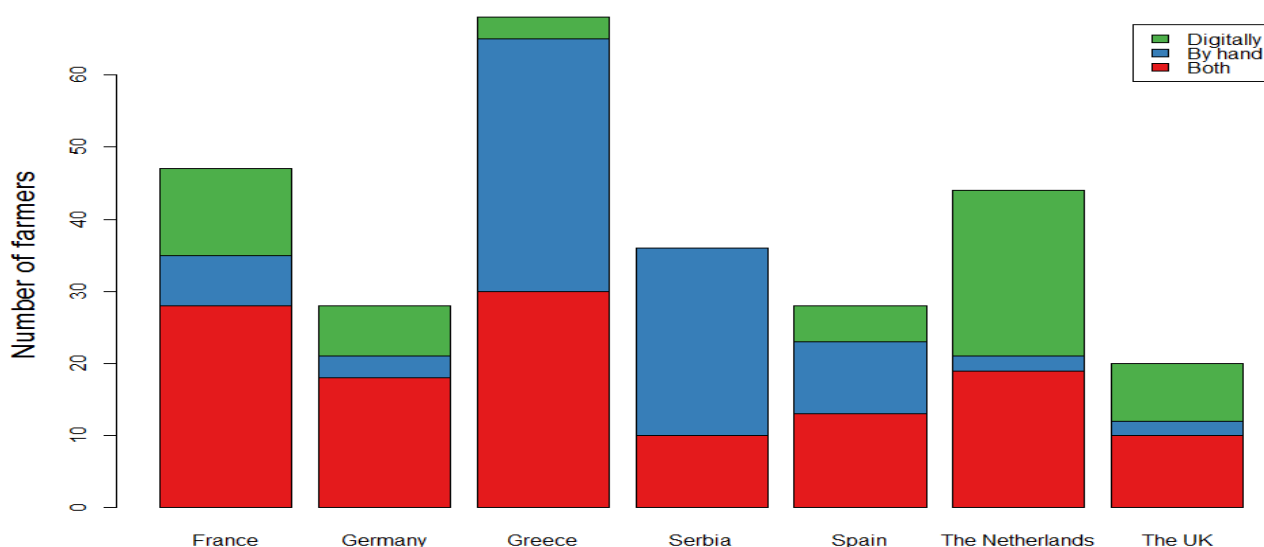


Figure 23 Method of data documentation in each country

3.4 General needs

Farmers' technological needs were addressed by asking short, open, optional questions. Short open answers were coded into categories that best reflected the answer content. In the first of the open questions, we asked farmers if they like to experiment, and if so, what types of experiments do they do. There were 208 farmers (76.7%) who said they experimented on their farms. In the upcoming deliverables, the types of technology that farmers experiment with will be explored more in depth. Only 13% of those farmers did not provide any example of the types of experiments they conducted. Most of the remaining farmers mentioned some of the following key terms in describing their experiments:

- Cover cropping: including green manure (13 times)
- Cropping patterns: includes trying new varieties, rotations (34 times)
- Cultivation: includes seeding, drilling, tillage, soil management and other management methods (29 times)
- Disease control: biological control, tree pruning (9 times)
- Inputs: reducing and adapting fertilizer, herbicide, or fungicide applied (22 times)
- Irrigation: methods and management to reduce water (7 times)
- Equipment: building, adapting, and adjusting machinery to improve work processes, testing new technologies (54 times)

These key terms and key phrases are not exclusive and may tend to overlap each other thematically, but present an approximate idea of where farmers' efforts have been concentrated, and highlight in which aspects of farming SFT could be most relevant. The strongest trend is for

farmers to experiment with new technologies when they are available and adapt their machinery when needed. Some of the experiments with new technologies are related to reducing or optimizing the inputs applied to crops, post-harvest technology (e.g. washing or drying equipment), or other cultivation techniques such as seeding or drilling. Many others report experimenting with different crop varieties, some using older varieties, other focusing on legumes, and still others focusing on cover crops or green manures.

We also asked farmers if they could describe an improvement to existing machinery or SFT to make it more acceptable or useful for farmers. In total, 146 farmers (54%) provided suggestions for existing SFT. These responses reflect that the existing technology may cover needs, but that the access to them and how they specifically work for farmers may be limiting their adoption. Some farmers also report that the problem is internet infrastructure and other mention a lack of precision in satellite data. We grouped most of their responses into 4 categories that reflected the range in suggestions:

- 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)
- Technology system (32 times, 22% of responses):
 - Simplification and consolidation of SFT and apps (8 times)
 - Compatibility between devices (24 times)
- 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)
- Data (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, it seems that compatibility between devices, or lack thereof, which is a major hurdle for SFT success. Some of this may be achieved by reducing the complexity of SFT at the device level, or by improving data transfer between devices or transforming data collected by a device into useable and accessible information.

Lastly, we asked farmers what the one piece of technology is that would be the most useful to them and their farm – regardless of whether it exists or not. There were 183 responses (67% of farmers surveyed) to this question. Most of the answers fit into the following categories:

- Infrastructure to enable the use of SFT (i.e. internet connection) (4 times, 2%)
- Robots for monotonous work processes (e.g. weeding, hoeing, harvesting) (44 times, 25%)
- Real-time diagnostics via drones, satellite imagery, or smart phone sensors (e.g. soil characteristics, weather, nutrient needs, disease) (41 times, 22%)
- Improved irrigation management (6 times, 3%)

- Integration of various SFT (18 times, 10%)
- Integrated farm management information system to connect all aspects of the farm (8 times, 4%)
- Data presentation for information use (17 times, 9%)
- Lighter and smaller field machinery (to reduce impact on soils, reduce fuel use) (6 times, 4%)
- GPS and VRT (30 times, 16%)
- Aerial imagery (5 times, 3%)
- Apps (6 times, 3%)

When asked what the technology is that farmers could use, many mentioned improvements to existing SFT and systems. The largest proportion of farmers listed robots or autonomous machines for monotonous work processes. Second most frequently mentioned included real-time diagnostics, whether it is for soil, plant needs, or diseases. What would make such diagnostic tools successful for farmers would then be to ensure that receiving data in the form of usable information.

3.5 Specific questions SFT needs and ranking

Most specifically, we asked farmers to choose one of the 5 SFT types presented in photos based on which would be most useful or is most useful to their farm (Fig. 24). The SFT that farmers chose differed based on country, cropping system, and farm size. Autonomous machines and robots, were most frequently chosen in France, Greece, and Serbia as useful for conducting monotonous field tasks corresponding to the prevalent cropping systems. Most probably, in these countries the vineyard, orchard, and vegetable growers express interest in these technologies to avoid high personnel costs accrued due to high manual work needs. In Germany, the Netherlands and the UK, there is a high proportion of arable cropping and large scale open vegetable cropping, which could explain the emphasis on farmers' choice of GPS, controlled traffic, VRT related to tractors.

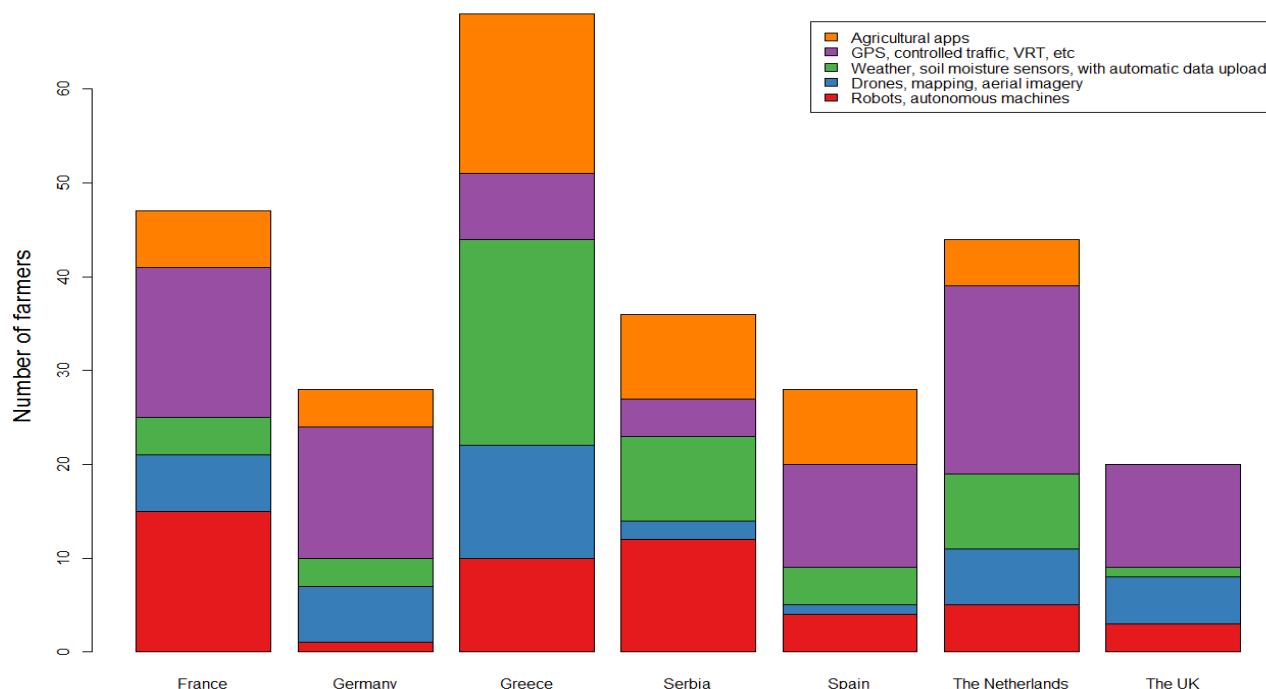


Figure 24 Relationship between country and SFT chosen as most useful by farmers.

When considering the farmers' choices of SFT according to cropping system, it was not surprising that arable farmers had the highest proportion of tractors with GPS and connected tools and settings (Fig. 25). GPS and similar devices (e.g. auto-steering) are mainly useful in arable crops, as it helps with guidance, while in orchard and vineyards, it does not seem important, since the lines of the permanent trees and bushes help keep tractors on track. Agricultural apps were

selected more vineyard and orchard farmers, as there are already many apps that are directed to such high added-value crops. Weather stations and soil moisture sensors with automatic data upload are more valuable for orchards and vineyards because they are used in southern countries (in this survey) 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.

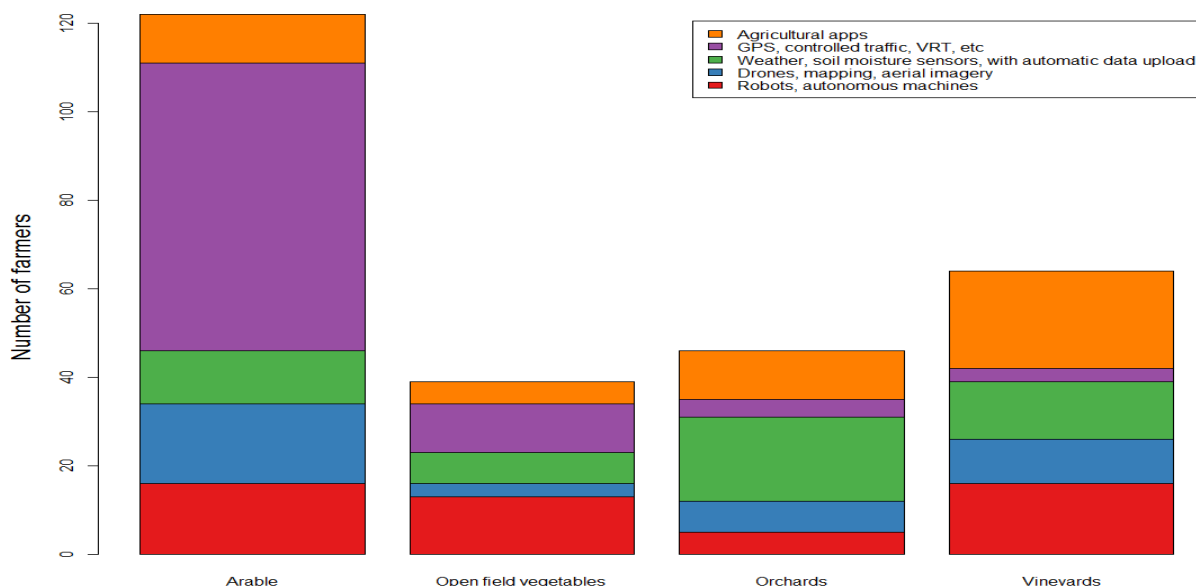


Figure 25 Relationship between cropping system and SFT chosen as most useful by farmers.

Farm size differences in preferred SFT reflect details correlated with country and cropping system level differences. Small farms from <2 to 10 ha would chose robots, weather and soil moisture sensors with automatic data upload, and agricultural apps most frequently, indicating that small sized SFT including robots, agricultural apps, and information based SFT would be most useful, due to the smaller size of their farms. Similarly, field-level data from drones or satellite imagery probably seemed less useful, as did tractors with GPS and their connected tools. There may likely have also been some collinearity in farm size, cropping system, and country (e.g. the high proportion of small farms in Greece that were mostly orchards and vineyards). Largest farms (> 500 ha) were arable and open field vegetable based, and therefore, there was an overwhelming perception of usefulness for tractor GPS and connected devices, along with field-level aerial imagery and mapping (Fig. 26).

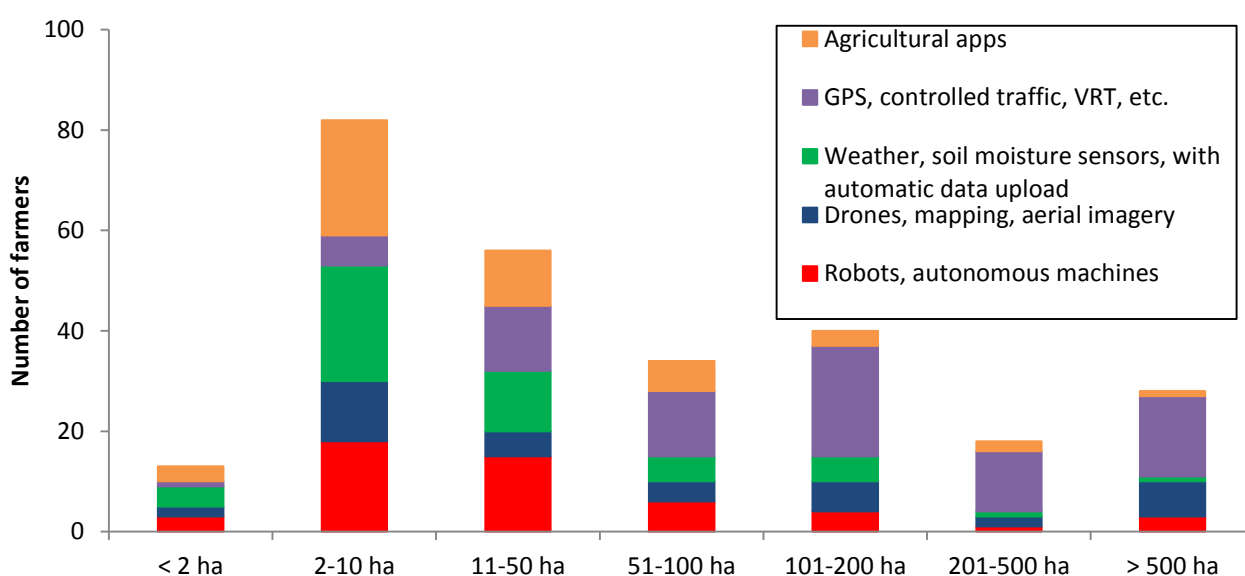


Figure 26 Relationship between farm size and SFT type that is or would be most useful to farmers

When asked to rank the 5 different types of SFT from least important (1) to most important (5) for farms, farmers ranked robots and autonomous machines as the least important, and both GPS for tractors and weather and soil moisture sensors with automatic data upload as the most important (Table 8). Differences in the way adopters and non-adopters ranked SFT were not that strong.

Table 8 Farmers' ranking of SFT types in terms of importance: 1. least important, to 5. most important

| | All farmers | Adopters | Non-adopters |
|---|--|--|--|
| 1 | Robots and autonomous machines | Robots and autonomous machines | Robots and autonomous machines |
| 2 | Drones, mapping, aerial imagery | Drones, mapping, aerial imagery | Agricultural apps |
| 3 | Agricultural apps | Agricultural apps | Drones, mapping, aerial imagery |
| 4 | Weather, soil moisture sensors with automatic data upload | Weather, soil moisture sensors with automatic data upload | GPS for tractors with associated controlled traffic, VRT, etc. |
| 5 | GPS for tractors with associated controlled traffic, VRT, etc. | GPS for tractors with associated controlled traffic, VRT, etc. | Weather, soil moisture sensors with auto data upload |

3.6 Adopters vs. non-adopters

Perceptions of adopters and non-adopters regarding challenges for farms, potential for SFT, and information sources showed subtle differences. Non-adopters tended to find challenges more important to overcome than adopters did. For example, 63% of the non-adopters found it important to improve biodiversity conservation on farms, whereas 55% of adopters perceived this as important. Similarly, 84% of non-adopters found it important to protect the soil on their farms, whereas 76% of adopters found this important. Similar trends were found for challenges “reduce harvest losses”, “reduce herbicide use”, “reduce insecticide”, and “reduce water use”. In the same vein, non-adopters did not agree as much with the SFT potential to help overcome some of those challenges on their farms, and also communicated more uncertainty regarding the SFT potential in those cases. For example, regarding the statement “SFT are better than previous tools”, 31% of the non-adopters agreed, and 63% expressed uncertainty, whereas 45% of adopters agreed, and only 49% expressed uncertain. Such patterns were similar for statements including “SFT are useful for farming”, “SFT decrease input costs”, “SFT improve farmers' work comfort”, “SFT improve farmers' work processes”, and “SFT increase productivity”. Both perceptions of challenges and SFT potential by non-adopters may reflect expectations that they have.

The largest differences in information sources that farmers relied on, not surprisingly, included agri-tech providers. There were 51% of non-adopters who found them an important source of information, whereas 61% of adopters found them important. More obviously, 21% of the non-adopters did not find them important sources of information, whereas only 8% of adopters did not find them important. In contrast, 41% of the non-adopters found the farmers' union important as a source of information, and 31% of adopters found them important. Private advice was important for 71% of adopters, but only for 50% of the non-adopters. Some of these patterns may be closely related to differences in information sources according to country, cropping system, and farm size.

Of the adopters, 41% had tractors with GPS, auto-guidance, controlled traffic, and VRTs. Weather stations and soil moisture sensors with automatic data upload are used by 16% of the adopters, and 18% of adopters use a variety of apps. Farmers start thinking about new SFT anywhere from a few months to 10 years after purchasing their SFT. Most adopters (83%) rely on suppliers, retailers, and makers of SFT to repair and maintain their SFT. The most important characteristics they mention that will determine whether or not they will purchase a new SFT depend on price (or cost reduction), usefulness of data (improvement of data presentation), universality of use and implementation (compatibility with other SFT and farm machinery), level of precision and efficiency, and added value to cultivation and production methods.

Non-adopters would need demonstrations (21%), personal tests (37% of non-adopters), conversations with an unofficial contact (18% of non-adopters), or cost-benefit models (25% of non-adopters) that reflect farm specificities before purchasing an SFT. The most often cited reason for not adopting an SFT was that they are not affordable (57% of non-adopters). 41% of non-adopters also cited their land as being too small for adopting an SFT, 16% said that the fitting technology was not available yet, and 11% said that SFT were too complicated. Most of the non-adopters use their farm machinery as long as possible, until it is not repairable, and mention using their equipment for as long as 30 years. Whether or not such technology-specific customs are compatible with each other remains to be investigated.

Only 27% of adopters used a subsidy to invest in SFT. 32% of adopters said that sharing costs with other farmers allowed them to use SFT on their farms. 58% of adopters tested the SFT before purchasing one or deciding to use it. Of the non-adopters, 88% said they would get SFT if they were supported through subsidies, and 66% said they would get them if could share costs with others. 93% of the non-adopters would like to use an SFT on a trial basis before deciding to get it. Similarly, the most important kind of information that they would need before deciding to get an SFT would be a personal test. These differences reinforce the cost issue for farmers in regard to SFT. Also, the value of personal tests before investing in or pursuing access to SFT plays a large role in farmers' attitudes.

4. Summary and concluding remarks

Here, we summarized the results from a survey conducted with 271 European farmers from 7 countries, who manage farms with 4 dominating cropping systems (arable crops, vineyards, open field vegetables and tree cultures), from a broad range of size classes, and include both adopters and non-adopters. In this study, when exploring farmers' perceptions of challenges to agriculture, SFT's ability to help overcome those challenges, how farmers get informed about developments in agriculture, and their relationship with technology, the country level context was the most effective. This was largely due to the specific conditions related to cropping system and farm sizes associated with those cropping systems.

A certain coherence across countries could be observed with regard to the most important challenges to agriculture, namely to reduce crop disease and to improve soil conservation. In contrast, the need of support to comply with regulations and to reduce harvest losses differed considerably among the countries and farm sizes. While some of the differences seemed to be explained with pedo-climatic conditions, others may be better explained with a more thorough understanding of farmers' values, which will have to be further investigated in future research.

Farmers' certainty regarding challenges they face in agriculture did not correspond to certainty in SFT's ability to deal with those (and other) challenges. In most cases, farmers expressed overwhelming uncertainty about SFT potential. However, there were strong tendencies for differences between countries with high adoption and countries with low adoption. We understood these differences between theory and practice to reflect high expectations that non-adopters have for SFT to improve their farming situation and the challenges that accompany their respective situation. Such differences were particularly noticeable in regards to expectations for SFT to improve farm income, farmers' work comfort, and ability of SFT to help make better management decisions.

European countries all have distinct agricultural knowledge and information and innovation systems. These differences were visible in the different sources of information that were relevant to farmers in the different countries and different farm contexts (cropping system and farm size). However, regardless of country or farm size, other farmers were relatively consistently of high importance for farmers. This suggests high levels of trust between farmers and highlights the importance of farmer-to-farmer networks for information.

Regardless of whether or not farmers are adopters or non-adopters of SFT, they stay abreast of

changes and developments in agriculture by keeping up to date with professional literature, attending trade fairs and workshops, and using social media. The majority of farmers specifically seek out information on SFT. Farmers' technological customs (mainly how they document their data) are somewhat related to level of adoption in each country, but for example, there does not seem to be a strong relationship between mobile phone ownership and SFT use. Such relationships may be further investigated.

Interestingly, farmers experiment to a large extent with technologies and cropping practices, and they develop many ideas of how to improve existing SFT. Although almost all had some overview of existing technologies, there seemed to be priorities with regard to SFT types, based on cropping system and farm size needs.

Results indicate that some of the key improvements to SFT are related to information (e.g. turning data into useable information, reducing complexity in data presentation), cost (e.g. reduction, cost-benefit clarity), and size (e.g. smaller SFT for small farms). Such results could provide input to SFT development and make them more appropriate to their challenges and needs. Data that is collected by SFT needs to be transformed to useful information for farmers. Furthermore, it seems that it is key to improve access to SFT via the more of the right kind of information, allowing farmers to test them, and adapting them to make them compatible with a larger range of existing farm machinery could foster greater adoption and dissemination.

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smart **AKIS**
Smart Farming Thematic Network



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Appendix 1

Final Smart-AKIS WP2 Survey Questionnaire

Aim of Smart AKIS:

Collect and disseminate applicable information regarding Smart Farming Technologies by establishing a network including farmers, researchers, advisers, suppliers and more.

Goals:

The goal of this survey is to understand farmers' interests regarding farming and smart farming technologies throughout Europe in different countries, farming systems, and farm sizes. As a result, we can contribute to the body of knowledge regarding innovation and SFT adoption processes by providing an overview of farmers' needs, ideas, and interests with regards to SFT.

Outcomes:

1. Farmers will receive the main results in a flyer or pamphlet during the winter. The results will link their interests in farming and technologies with characteristics like farm size, cropping system and country, so that farmers can see how their situation compares to that of other farmers. This can help farmers make informed choices regarding SFT.
2. This should help farmers understand their situation compared to other farmers and should help them decide on whether or not to get access to SFT, and if so, which type.
3. Information will be presented at international conferences. Farmers' interests and attitudes are relevant to the larger scientific community so that the research can be done more effectively.
4. Results will be interesting for the EU policy scene to adapt schemes to better support farmers in their job.
5. Results will also be interesting for the agricultural machinery and SFT industries so that they can produce items that are relevant to farmers' very diverse interests.
6. The information from this study will also be important for extension workers and farmers' organizations so that key issues related to innovations and technologies can be tackled and solved.

Privacy statement:

Personal data will be completely anonymized and will not be sold to any third parties or shared with other actors/parties. The information collected in these surveys will be anonymized. No one will be able to trace results back to the individual farmer or farm.

Instructions for farmer:

- This questionnaire focuses on farmers' interests. It will gather broad information related to farms, smart farming technologies (SFT), and farmers.
- The questionnaire is divided into several sections.
- First we will ask you about some basic information about your farm and the one particular cropping system that we are surveying you for,
- Then about technologies and your experience with them,
- Lastly we will ask questions about you.
- If a question is too sensitive to answer, please indicate so.
- In this survey, SFT are farm management information systems, precision agriculture, and agriculture automation and/or robotics. These may include smart phone apps and also enable different systems such as Controlled Traffic Farming.

Questionnaire

Farm

1. Country:
2. Region:
3. How would you describe your region (choose the one where most of the relevant cropping system is):
 - ☐ Flat
 - ☐ Hilly
 - ☐ Mountainous
4. Cropping system (choose main one):
 - ☐ Arable crops
 - ☐ Orchards
 - ☐ Open field vegetables
 - ☐ Vineyards
5. Will your farm's cropping system be continued in the next 5 years?
 - ☐ Yes
 - ☐ No
 - ☐ Don't know
6. Will your farm's cropping system be continued in the next 10 years?
 - ☐ Yes
 - ☐ No
 - ☐ Don't know
7. Legal status of farm:
 - ☐ Family farm or family company
 - ☐ Company without family shareholder
 - ☐ Cooperative farm
 - ☐ Other _____
8. **(Only if "family farm" was chosen in Question 7)**
Importance of farm for household income is estimated at about:
 - ☐ ____%
9. How is the majority of the farm's machinery owned?
 - ☐ Private
 - ☐ Cooperative
 - ☐ Rented

10. Total area cultivated / farm enterprise size:

- ☐ <2 ha
- ☐ 2-10 ha
- ☐ 11-50 ha
- ☐ 51-100 ha
- ☐ 101-200 ha
- ☐ 201-500 ha
- ☐ >500 ha

11. Land owned (ha or %): _____

12. Land rented in (ha or %): _____

13. Land rented out (ha or %): _____

14. Is farm machinery / SFT subcontracted out (with or without farmer)?

- ☐ Yes
- ☐ No

15. Are there any non-agricultural activities on farm?

- ☐ Yes
- ☐ No

16. **(Only if “yes” was chosen in Question 15)** What is it? _____

17. Other certification schemes (e.g. PGI/PDO in Serbia)?

- ☐ Yes
- ☐ No

18. **(Only if “yes” was chosen in Question 17)** Which one? _____

19. Does the farm receive direct payments? (Pillar 1 from CAP: greening, young farmer, etc.)

- ☐ Yes
- ☐ No

20. **(Only if “yes” was chosen in Question 19)** Is the payment necessary for the financial stability of your farm?

- ☐ Yes
- ☐ No

21. Does the farm receive any other subsidies? (Pillar 2 from CAP: diversification, agri-environmental, organic farming, etc.)

- ☐ Yes
- ☐ No

22. **(Only if “yes” was chosen in Question 21)** Which one? _____

SFT

Choose one SFT type from the photos. You may have direct experience with the SFT you chose, because you use it, or you may have heard about it from someone else. Whether or not you own an SFT is not important for the following questions. It is important what you think about or know about the SFT you chose. Please think about the SFT you chose when answering the following questions.

23. Which SFT was chosen?

- ☐ Type 1
- ☐ Type 2
- ☐ Type 3
- ☐ Type 4
- ☐ Type 5

For each of the next questions, I will read you a statement, and ask you to decide how much you do or don't agree with it based on the SFT you chose.

24. The SFT you chose is useful for farming.

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Agree
- ☐ Strongly agree

25. The SFT you chose is better compared to the technology or tools that were available before.

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Agree
- ☐ Strongly agree

26. Using the SFT you chose increases productivity compared to not using it.

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Agree
- ☐ Strongly agree

27. Using the SFT you chose decreases input costs compared to not using it.

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Agree
- ☐ Strongly agree

28. The SFT you chose provides information to help you make better management decisions.

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Agree
- ☐ Strongly agree

29. The SFT you chose helps reduce pollution from farms (for example, nutrient run-off).
- ☐ Strongly disagree
 - ☐ Disagree
 - ☐ Agree
 - ☐ Strongly agree
30. The SFT you chose improves the impact of farms on nature (for example, biodiversity).
- ☐ Strongly disagree
 - ☐ Disagree
 - ☐ Agree
 - ☐ Strongly agree
31. The SFT you chose improves farmers' work processes and workload.
- ☐ Strongly disagree
 - ☐ Disagree
 - ☐ Agree
 - ☐ Strongly agree
32. The SFT you chose improves farmers' work comfort.
- ☐ Strongly disagree
 - ☐ Disagree
 - ☐ Agree
 - ☐ Strongly agree
33. The SFT you chose improves farms' income.
- ☐ Strongly disagree
 - ☐ Disagree
 - ☐ Agree
 - ☐ Strongly agree
34. Which SFT from all the pictures is or would be most useful to your farm?
- ☐ Type 1
 - ☐ Type 2
 - ☐ Type 3
 - ☐ Type 4
 - ☐ Type 5
35. Do you have or use an SFT?
- ☐ Yes (**continue with 36: adopters**)
 - ☐ No (**continue with 52: non-adopters**)

Adopters: if "yes" was chose in Question 35, continue here with Question 36

36. Which SFT do you have or use (most often)? _____
37. Did you test the SFT before getting it?
- ☐ Yes
 - ☐ No

38. Where did you get the information you needed for getting it?

39. Did the introduction of SFT change your farming practices?

- ☐ Yes
- ☐ No

40. How long did it take for you to become comfortable using the SFT?

_____ (days, weeks, months, years?)

In the next few questions, you will be asked if you disagree or agree with the following statements.

41. It is easy to work with SFT.

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Agree
- ☐ Strongly agree

42. It is easy to get support for SFT.

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Agree
- ☐ Strongly agree

43. SFT are economically justified / the cost-benefit of the SFT is as you expected.

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Agree
- ☐ Strongly agree

44. Did a specific external subsidy other than the direct farm payment give you an opportunity to invest in SFT?

- ☐ Yes
- ☐ No

45. Sharing costs with other farmers has allowed you to use SFT.

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Agree
- ☐ Strongly agree

46. SFT are reliable.

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Agree
- ☐ Strongly agree

47. SFT require a lot of maintenance.
- ☐ Strongly disagree
 - ☐ Disagree
 - ☐ Agree
 - ☐ Strongly agree
48. Who repairs and maintains your SFT?
- ☐ You (farmer being interviewed)
 - ☐ Supplier/retailer/maker of SFT
 - ☐ Independent company
 - ☐ Public service
 - ☐ Other farmer
 - ☐ Other _____
49. How old is your SFT (in years or months)?
- ☐ _____
50. When will you get your next SFT (in years or months)?
- ☐ _____
51. What is the most important SFT characteristic that will determine what you get?
- ☐ _____

Non-adopters: Continue here only if “no” was chosen in Question 35

52. Would you use SFT on a trial basis before deciding to use it?
- ☐ Yes
 - ☐ No
53. What kind of information would you need before deciding to get it (tick most important)
- ☐ Demonstration
 - ☐ Cost benefit model to reflect farm specifics
 - ☐ Video
 - ☐ Conversations with unofficial contact (neighbour, other farmer)
 - ☐ Conversations with office contact (advisor, official, someone paid for their service)
 - ☐ Personal test
 - ☐ Other _____
54. Would you get SFT if it were supported through subsidies?
- ☐ Yes
 - ☐ No
55. Would you get SFT if you shared costs with others?
- ☐ Yes
 - ☐ No

56. What are your reasons for not adopting SFT? (Tick all that apply)

- ☐ Land is too small
- ☐ Not the fitting technology available yet
- ☐ Not interested in the available technology
- ☐ Not affordable
- ☐ Too complicated
- ☐ Other

57. (Only if “other” was chosen in Question 56) What is your reason for not adopting SFT?

- ☐ _____

58. What is your most important machine or technology? (Combine, tractor, dryer, etc.)

- ☐ _____

59. Do you frequently renew your farm equipment?

- ☐ Yes
- ☐ No

60. How long do you use your farm equipment before thinking about investing in something new?

- ☐ _____

61. Have you seen what other farmers do using SFT?

- ☐ Yes (continue with Questions 62 and 63)
- ☐ No

62. (Only if “yes” was chosen in Question 61): Did this raise your interest in SFT?

- ☐ Yes (which SFT: _____)
- ☐ No

63. (Only if “yes” was chosen in Question 61) Did this confirm your attitude regarding SFT?

- ☐ Yes
- ☐ No

All farmers: now resume for both adopters and non-adopters

64. Do you like to experiment with doing things on your farm (can be anything that means trying to change or adapt something on the farm)?

- ☐ Yes – by yourself
- ☐ Yes – with other farmers
- ☐ Yes – with advisers or researchers
- ☐ No

65. (Only if “yes” was chosen in Question 64) Please provide an example of your experiment:

66. Have you sought out information on available and appropriate SFT for your farm?

- ☐ Yes
- ☐ No

67. How often do you visit agricultural fairs, field days, or exhibitions?

- ☐ More than once a year
- ☐ Once a year
- ☐ Less than once a year
- ☐ Never

68. What was the most recent informational product or event related to farming or SFT you sought out?

(Please choose one)

- ☐ Professional literature (e.g. farmer association magazines)
- ☐ Scientific journal
- ☐ Advertisement
- ☐ Exhibitions or trade fair
- ☐ Seminars or workshop
- ☐ Demonstration farm
- ☐ Social media
- ☐ Others

In the following points, rank the challenges that make or could make SFT more important for your farm. (Please rank each: 1 not crucial, 5 very crucial)

69. Reduce water use

| | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|

70. Reduce N use

| | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|

71. Reduce diseases

| | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|

72. Reduce weeds

| | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|

73. Reduce fungicides

| | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|

74. Reduce insecticides

| | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|

75. Reduce herbicides

| | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|

76. Reduce harvest losses

| | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|

77. Biodiversity conservation

| | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|

78. Soil conservation

| | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|

79. Compliance with regulations

| | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|

In the following points, rank the challenges for SFT that would make them more relevant to farmers. (Please rank each: 1 not crucial, 5 very crucial)

80. Improve user safety of machinery

| | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|

81. Improve data storage

| | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|

82. Improve data transfer between devices (e.g. tractor and computer)

| | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|

83. Improve social structures (relationships between farmers and different types of organisations) to provide more information on and access to technologies

| | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|

84. Improve data presentation for easier understanding and decision support

| | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|

85. Improve regulations regarding data ownership

| | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|

The following questions are about the farmers' opinions about technology in general.

86. Technology can improve farming.

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Agree
- ☐ Strongly agree
- ☐ Don't know

87. Technology can help farmers comply with regulations (e.g. CAP Greening).

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Agree
- ☐ Strongly agree
- ☐ Don't know

88. Technology can support farmers' recognition of work by public.

- ☐ Strongly disagree
- ☐ Disagree
- ☐ Agree
- ☐ Strongly agree
- ☐ Don't know

Show photos again.

Please rank technology you see here in the photographs in order of least importance (1) to most important (5), such that each number only appears once (e.g. Photo 1: 3, Photo 2: 4, Photo 3:1, Photo 4: 5, Photo 5: 2) .

89. Photo 1:

90. Photo 2:

91. Photo 3:

92. Photo 4:

93. Photo 5:

Farmer

94. Age:

- ☐ < 20
- ☐ 20-29
- ☐ 30-39
- ☐ 40-49
- ☐ 50-59
- ☐ >60

95. Gender:

- ☐ Male
- ☐ Female
- ☐ Prefer not to say/Other

96. Nationality:

97. What is the highest level of education you completed?

- ☐ Elementary (approximately 4-7 years of general education)
- ☐ Secondary school (approximately 8-12 years of general education)
- ☐ Technical school and/or apprenticeship (approximately 2-4 years follow-up after secondary school)
- ☐ University (any level, Bachelor, Master, or PhD)
- ☐ Other: _____

98. Is the interviewee the farm head?

- ☐ Yes
- ☐ No (Manager/parent/offspring/other)

99. Is there a farm successor or someone who will take over the farm?

- ☐ Yes
- ☐ No

In the following points, please rank the importance of each informational source relevant to farmers. (Please rank importance of each source, 1 least important to 5, most important):

100. Public extension service

| | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|

101. Private advice

| | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|

102. Farmer association

| | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|

103. Agri-tech provider

| | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|

104. Agri-input supplier

| | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|

105. Bank

| | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|

106. Other farmers

| | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
107. Farmer's union

| | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
108. Machinery services or contractor

| | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
109. Family

| | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
110. Others (including managers)

| | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
111. Why did you become a farmer?
- ☐ Tradition (family, farm inherited)
 - ☐ Profession of choice
 - ☐ No other choice
 - ☐ Other

In the following points, please rank the importance of each personal value in farming. (Please rank importance of each source, 1 least important to 5, most important):

112. Economic

| | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
113. Conservation

| | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
114. Lifestyle

| | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
115. Role in local community and food system

| | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
116. Working outside

| | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
117. Other

| | | | | |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
118. What other values come to mind: _____
119. How would you rank your satisfaction with farming?
- ☐ Very unsatisfied
 - ☐ Unsatisfied
 - ☐ Satisfied
 - ☐ Very satisfied
120. **(Optional)** Are there reasons for dissatisfaction? _____

In the following questions, I will ask you about your relationship to technology to better understand your interest in SFT.

121. How do you document your farm data?
 - ☐ By hand
 - ☐ Digitally
 - ☐ Both

122. Who manages the data collected?
 - ☐ You
 - ☐ Family member
 - ☐ Someone else (extension worker, company employee, other)
 - ☐ A combination

123. Do you use a mobile phone?
 - ☐ Yes
 - ☐ No

124. **(Only if “yes” was chosen in Question 123)** How long have you used a mobile phone for? _____

125. **(Only if “yes” was chosen in Question 123)** What do you use your mobile phone for? **(Tick all that apply)**
 - ☐ Agricultural apps
 - ☐ Weather apps
 - ☐ Photos
 - ☐ Communication with other farmers/cooperative/association **(phone or message)**
 - ☐ Emails
 - ☐ Social media from other farmers, demonstrations, etc.
 - ☐ Internet surfing

126. **(Only if “agricultural apps” was chosen in Question 125)** Which app do you use most? _____

127. Please describe the one piece of technology that you would like to have or need **(that does or does not already exist)** that would be most useful to you or your farm.
(Open question, could describe a process that could be made more efficient, a certain piece of tech that would complement others, some farming challenge that could be solved with a certain type of technology...)

128. Give one improvement to an SFT that you know to make it more acceptable (easier to use, more reliable, compatible with existing tech, cost/benefit model tool, etc.)

129. Is there anything else that you want me to know about your opinion on SFT and the way you make decisions about integrating SFT into your farming?

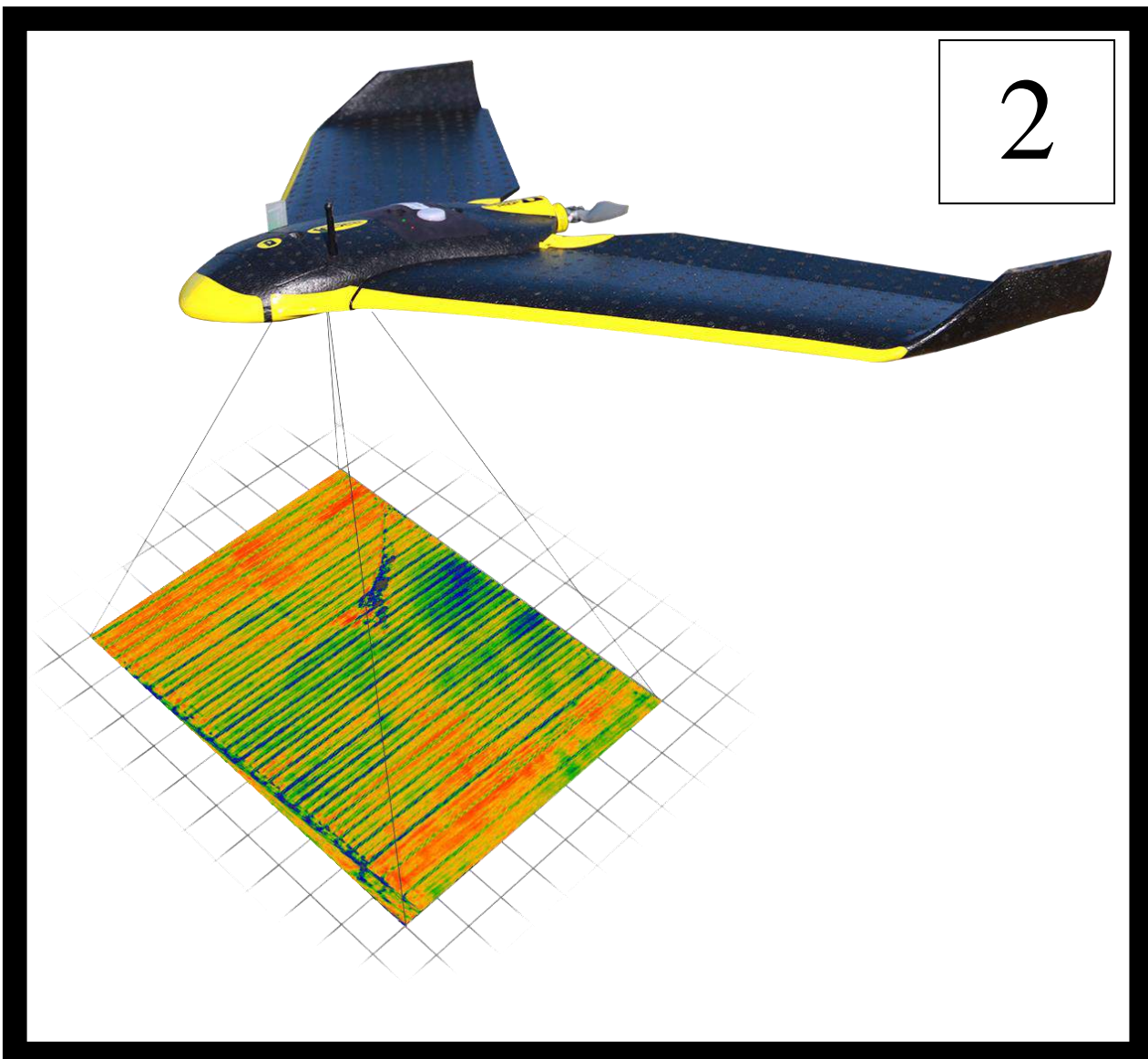
Appendix 2

Type 1: Robots and autonomous machines



Autonomous robots: above, pruning vines in a vineyard (Wall-Ye V.I.N. robot), and below, weeding and using sensors to monitor a vegetable crop (Carre)

Type 2: Drones and their data



Drones: map fields, analyse crop nutrient needs, and provide maps for precise fertilizer, pesticide or irrigation application (Airinov).

Type 3: Connected tools (data acquisition and automatic upload)



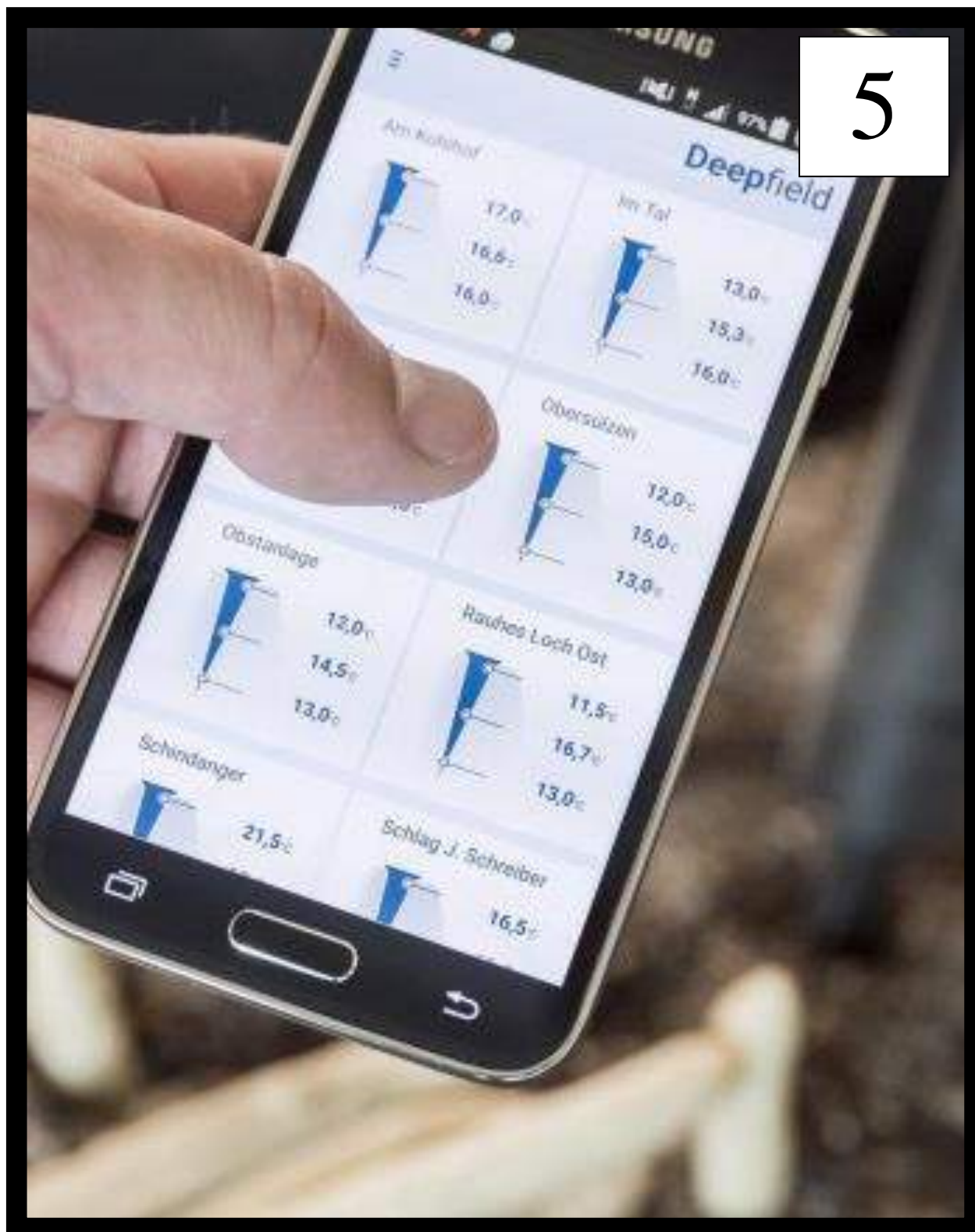
Climate related (connected) tools with data acquisition and automatic upload: for example, soil moisture sensor with automated data upload (figures on left: www.ICTinternational.com), or automated weather station (figure on right: ©2015 Pat Guinan, MU Extension)

Type 4: Combination of GPS, setting data, and attached machines



Top figure: GPS guidance system for controlled traffic farming or the settings data of the attached machine (Top left: Kverneland, top right: <https://www.agric.wa.gov.au>, middle: Fritzmeier, bottom: <http://www.informedfarm.com/variable-rate-nitrogen>).

Type 5: Agricultural apps



Smartphone apps for agriculture, here for monitoring crop conditions (Bosch-Deepfield Robotics).

Appendix 3

The following hypotheses guide the structure of the questionnaire.

Hypotheses according to farms:

Hypothesis 1.1

The main cropping system will play a large role in SFT interest. For example, arable farming may be more likely to incorporate SFT, since it is more large-acreage than other cropping systems.

Hypothesis 1.2

The longer term farmers can plan, the more interested in SFT they may be, since this means they may be more willing to invest in SFT.

Hypothesis 1.3

The more land that is owned by a farm, the more strongly correlated it will be with farmers' interest in SFT.

Hypothesis 1.4

Specialization or certification will influence interest in SFT adoption by either providing the information which farmers need to fulfil certain requirements, or by providing the financial back-up.

Hypotheses according to smart farming technologies:

Hypothesis 2.1

Higher perceived relative advantage positively correlate with farmers' interest in SFT.

Hypothesis 2.2

Higher compatibility of technology with farming values will positively correlate with farmers' interest in SFT.

Hypothesis 2.3

The more able a farmer is, or the more opportunities a farmer has, to try out SFT will increase farmers' interest in SFT.

Hypothesis 2.4

The easier it is to see a positive outcome of the SFT, the more likely the farmers are to be positively interested in SFT.

Hypothesis 2.5

The more informed a farmer is regarding the current SFT developments (e.g. development from sensor to smart phone), the more likely the farmer is to adopt an SFT.

Hypothesis 2.6

Greater perception of problems in agriculture will be positively correlated with interest in SFT in general.

Hypothesis 2.7

The more positive the image of SFT, as perceived by farmers, the greater interest they have in adopting it.

Hypothesis 2.8

The more useful technology seems for farm and cropping system, the more likely farmers will be interested.

Hypotheses according to farmers:

Hypothesis 3.1

Age, gender, education, and experience will all influence farmers' attitudes/ interests in SFT and farming together with other factors, but alone won't have any real influence on SFT.

Hypothesis 3.2

Farmers' membership in certain cooperatives and/or associations will influence their attitude towards SFT due to the information flows they gather.

Hypothesis 3.3

Farmers' interest and values in farming will reflect their interest in SFT.

Hypothesis 3.4

Farmers' use of technology in everyday life will be positively correlated with their interest in socio-technical innovations and SFT.