

D1.2 Research project results on Smart Farming Technology



smartAKIS
Smart Farming Thematic Network



Document Summary

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Author(s): Sandra L. Wolters, Thanos Balafoutis, Spyros Fountas, Frits K. van Evert

Contributor(s):

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Abstract

Smart-AKIS project aims at examining the suitability and use of Smart Farming Technologies (SFT) in EU Agriculture involving farmers, the agricultural machinery industry, academia, research centers, agricultural engineering and public bodies.

The purpose of this document is to prepare a structured report and a database of the European projects based on the methodology established at D1.1 where a relation of the key points of our project will be addressed.

This report is organized in four chapters. The first chapter introduces current work on the Smart-AKIS project as well as the objective of this document in the overall Smart-AKIS exercise. The second chapter goes into more detail on the methodology that has been used and chapter three is about interim results. The last chapter summarizes conclusions.

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1 Introduction

Arable farming faces several challenges, amongst which are the need to reduce the use of pesticides, fertilizers and energy, to decrease adverse effects on the environment, to achieve safe and transparent agri-food chains, and to implement the Greening of the Common Agricultural Policy (CAP) of the EU.

New opportunities are emerging in arable farming, as a result of rapid development of communication networks (mobile telephony, high speed connections and narrow band, short and long range) and availability of a wide range of new sensors. In an agricultural context, these technologies help capture and transmit geo-localized real-time information at low cost. Once gathered, processed and analyzed, this data can help to measure the state of the agro-environment (e.g. soil, crop and climate) and when combined with agro-climatic and economic models, forecasts and advices for better tactical decisions and management of technical interventions can be given. Precision crop management has a major significance for future cropping systems.

Precision agriculture is a farming management concept based on observing, measuring and responding to inter and intra-field variability in crops. Multiyear crop characteristics are tied to topological terrain attributes. Precision agriculture was largely made possible by the emergence of widely available GNSS technology. This has resulted in the possibilities for farmers and researchers to geo-reference many agronomic variables.

The underlying concept for Smart Farming Technology (SFT) is precision agriculture. The Smart-AKIS project is set out to investigate the role of SFT in the development of future agriculture and try to close the research and innovation divide in the SFT sector. Smart farming technology can help achieve higher production outputs with fewer costs in compliance with agricultural environmental standards.

Attention for precision farming and smart farming technology is growing rapidly. It is therefore necessary to gain more insight in the types of SFTs that are being developed or have been developed. There have been several overviews of the current status of SFT development. Previous research includes a survey about adoption rates of proposed technologies, the CropLife/Purdue Precision Ag Survey developed at Purdue University. This is asking retail crop input dealers (in the US) regarding their use of precision agriculture

services. Moreover, multiple reviews have been done on farm management information systems (FMISs). For example: (Fountas et al., 2015) have reviewed the state of the art in FMIS from both an academic and commercial perspective. Lewis (1998) provided information on the evolution of FMIS and Kaloxylas et al. (2012), (Kitchen, 2008) and (Kuhlmann & Brodersen, 2001) took an outlook on FMIS in the future. These efforts have contributed to an increased understanding of previous, current and possibly future developments in SFT.

Smart-AKIS aims to provide an extensive overview of SFTs. Although some progress has already been made to synthesize current knowledge on smart farming, many important questions remain. As a result a new synthesis on current knowledge will be provided in the Smart-AKIS project.

A few questions are considered to be of particular relevance for Smart Farming.

Questions:

1. Which SFTs are there?

Which SFTs can be found and what is their level of technological readiness? The technological readiness level (TRL) is an indication of the development stage of the SFT. It is expected that we will find SFTs that are still in the conceptual stage, as well as SFTs that have been proven successful in the operational environment.

2. What kinds of benefits do these SFTs bring and conversely: what kinds of desirable benefits are poorly addressed?

We aim to examine the potential of SFT by looking at the benefits they will bring. Benefits could for example be a cost reduction, reduced emissions, reduction of physically demanding labour, etc. Furthermore, it is important to be able to identify what benefits are poorly addressed/covered by SFTs that are currently being developed. In this way knowledge gaps can be identified.

3. Where are SFTs currently used?

We are interested in the geography, type of farm/cropping system, type of farmer and production phase of the SFTs.

4. Which SFTs are used on the largest number of hectares?

After retrieving information on the different SFTs that are currently used, we would also like to find out more on the farm sizes that are related to different types of SFT.

5. What kinds of SFTs are research projects focusing on / what kinds of SFTs are on the market?

Attention will be paid to the differences in SFTs that are developed in the market vs scientific SFT development.

For answering these questions in a structured manner we will go in to more detail about the methodological steps that have been taken regarding data retrieval and processing.

Deliverable 1.1 reported on the methodology and standards used. In the past months large progress has been made in the retrieval of data via the survey about relevant SFTs. Several new findings will be explained.

This document is written simultaneously with Deliverable 1.3 where available in the market industrial SFTs will be elaborated. This report will focus on interim results from research publications. The following sections will describe the methodology (Section 2), results (Section 3) and interim conclusions (Section 4).

2 Methodology

A systematic review was conducted in order to answer the research questions stated in chapter 1. To provide more insight in current SFT development, we have worked on two literature collection methods in order to build a database containing all current relevant SFTs.

We researched scientific journals, EU-funded projects, national projects, and markets. A distinction was made between SFTs from scientific articles, scientific projects and marketed products.

Web-search resulted in a large amount of relevant research projects. A library query containing a collection of keywords has resulted in a large amount of articles, that have been carefully progressed through manual filtering. Both sources of research publications entered a database via an online survey.

2.1 Retrieval of projects

An active search was done for EU-Funded projects. Horizon 2020, FP7 and ICT-AGRI programmes were collected from the CORDIS website of the European Commission.

A selection query was used in order to select relevant articles from the Horizon 2020 and FP7 collection. In this selection relevant keywords have been used to identify SFT related projects.

```
[ '%sensor%', '%automat%', '%decision-support%', '%dss%', '%database%', '%ict%',
'%autonom%', '%robot%', '%gps%', '%gnss%', '%information system%', '%image analysis%',
'%image processing%', '%precision agriculture%', '%smart farming%', '%precision farming%',
'%agricult%', '%crop%', '%arabl%', '%farm%', '%vineyard%', '%orchard%', '%horticult%'
'%vegetabl%']
```

the '%' helps to also get words from which the keywords is a part. The complete query can be found in appendix I.

This selection was supplemented by projects from ICT-AGRI. These projects have been selected through a manual selection procedure. After selection for both sources of research projects 201 projects were entered in the survey.

2.2 Retrieval of articles

For our library search several reference databases were considered:

- Scopus (www.scopus.com): broad coverage: not only agriculture, not only top journals
- Web of Science (www.webofknowledge.com): coverage focused on top journals
- CAB Abstracts (<http://www.cabi.org/>): only agriculture, presence of grey literature
- Agricola (<https://www.ebscohost.com/>): only agriculture, presence grey literature
- Agris (<http://agris.fao.org/>): specific for agriculture

It was decided to use the database with the highest possible coverage in order to answer our research questions in the best possible manner. Therefore Scopus Elsevier B.V. was used to collect scientific articles.

A library query was developed to search articles that might describe SFTs. The query consisted of two parts: a first part that aimed to select all articles related to technology, and a second part that aimed to select all articles related to arable farming. The two parts of the query were joined with an “AND” clause. The selection of keywords was supplemented by considerations on the scope of relevant time and subject related settings.

The complete query can be found in Appendix I. A copy of part of the query is written below as it was used to select articles by formulation of keywords:

[sensor, decision-support, dss, database, ict , automat, autonom* ,robot*, gps, gnss ,information system, image analysis, image processing, precision agriculture, smart farming, precision farming, agriculture, crop, arable, farm, vineyard, orchard, horticulture or vegeTable]*

Keywords ending with “ * “ could have different endings (e.g. automat* could mean automatic or automated etc).

Results were limited by year, document type (article), subject type (agriculture) and language (English). For our purpose we have collected papers only from 2010 and later, in order to focus on recent SFTs that are likely of interest to modern farmers. Ten key papers considered relevant for our subject were used to verify the results of the query. When these 10 papers were included in the query result, this increased confidence that we had formulated an appropriate query.

The Scopus query has resulted in 11090 selected articles that are expected to be holding information on smart farming technology. The selection was followed by a manual sorting procedure.

2.3 Manual selection procedure

Among the 11090 articles resulting from the Scopus query, there were many that were not relevant to Smart-AKIS. Therefore, a manual selection procedure was used to select only the articles that are relevant for our project, namely, articles describing a technology that can (or could be) used by a farmer in his or her daily farming practice. The manual selection of articles was done in two rounds.

In the first round, we focused on the question “*Is this a relevant SFT?*”. The abstract of each scientific article was read to select the most related ones to SFT. Some important decisions on the relevance of articles were made in considerations between all partners. It was decided that some restrictions would reduce the scope of the articles to a level that would better represent SFT. Anything related to water or fish farming, post-harvest procedures and plant breeding and genetics was removed from our list of selected articles. Anything related to storage, processing, distributing and marketing was also not included in our selection.

We used an exclusion approach and removed the following kinds of papers based on information contained in the abstract:

- Remove anything related to post harvest and food processing
- Remove Anything related to Evapotranspiration calculations
- Remove Anything related to land suitability (select only DSS related to crops suitability)

- Remove Anything related to water management, like droughts (but include anything related to irrigation)
- Remove Anything related to tractor engines

In the second round, we attempted to locate the full paper and evaluate in more detail the applicability of the SFT.

The two selection rounds were time-consuming. Three people have been working on this sorting from WR, per sorting round all three people been busy for one week (approx. 36 hours) each per sorting round. From AUA 3 people have also been sorting articles in two rounds, for approximately one week per person in each sorting round as well. The total amount of time spent was thus approx. 12 person-weeks.

For this procedure, Roy Rosenzweig's programme Zotero was used to guide the sorting procedure and to keep track of the number of articles.

SFTs related to the growing and harvesting of open field crops are included in the selection; greenhouse cultivation was excluded.

There were 11090 articles selected. The first selection round filtered out articles that were not directly related to SFT in the field, reducing the amount of papers to +/- 1337 papers. The second selection round has been done to select SFTs that are of practical relevance and in a practical phase of development. A final selection of 718 articles was loaded in a database. This data was supplemented with the 201 EU projects.

2.4 Survey

A survey was constructed for recording data about the papers in a database. The survey was distributed online via a link on the www.smart-akis.com webpage. The construction of the survey was done under EIP-AGRI format for projects and practices. It was used to retrieve information from three separate types of sources for SFT information, namely projects, scientific articles and industrial SFTs. The reader should recall that only the first two category's will be elaborated in this report. The latter category will be considered in D1.3 on market SFTs.

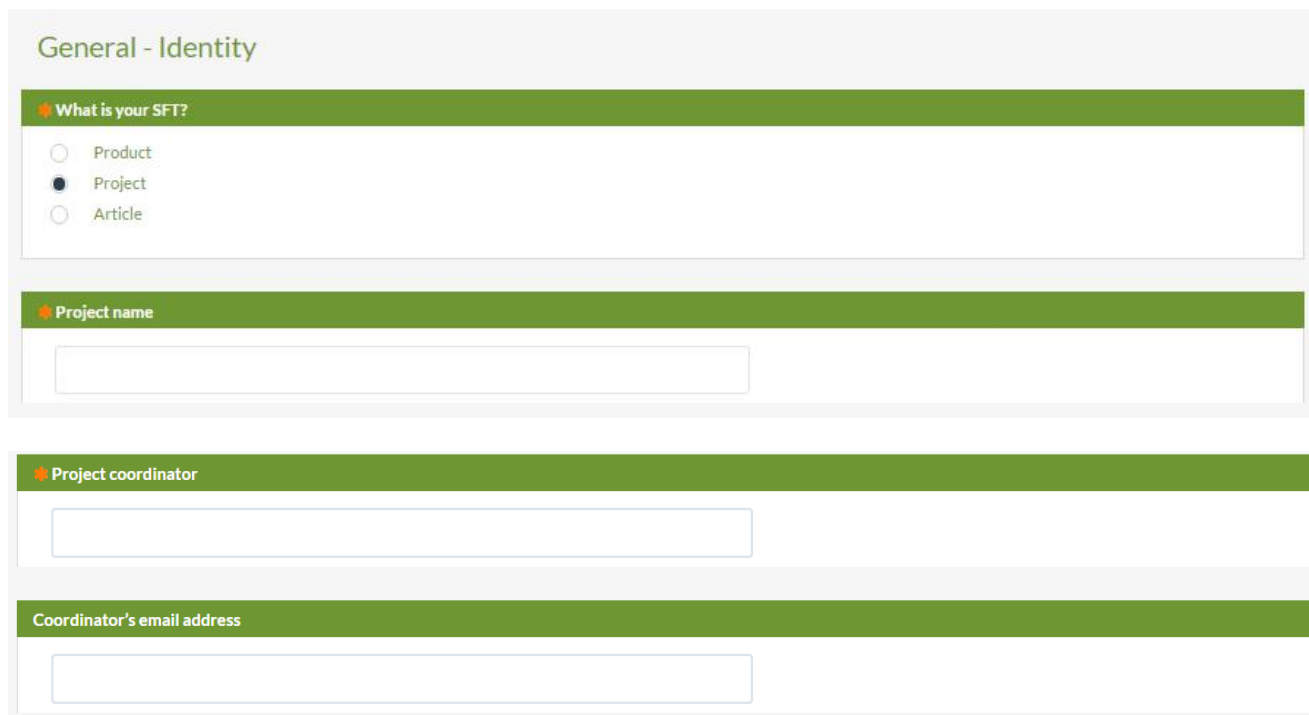
The survey is about roughly a few categories of relevant information on SFTs from articles and projects:

- Required general background information on articles and projects
- Questions about innovation
- Questions about the adoption of the SFT.

2.4.1 Survey for projects

The Smart-AKIS survey questions specific to the SFT type “project” are listed in Figure 1 below.

The survey for projects starts off with general identity questions, including Project name, Project coordinator and his/her email address. A next step is to retrieve information on possible project partners that are involved, up to 90 project partners could be entered. The project period could be entered. The project status could be ongoing or finished. A few suggestion were done for the source of funding, with the option to enter other sources of funding that were not included in the options. The objective and a description of the project was also asked.



The screenshot displays the 'General - Identity' section of the Smart-AKIS survey form. It features four distinct input areas, each with a green header bar and a corresponding text input field below it. The first section, titled 'What is your SFT?', contains three radio button options: 'Product', 'Project' (which is selected), and 'Article'. The subsequent three sections are 'Project name', 'Project coordinator', and 'Coordinator's email address', each followed by a single-line text input field.

Project partners

Enter no more than 90 partners. Once you fill in the existing field, a new empty field will appear. Please enter one partner per field.

Project period

Start of the project (year)

End of the project (year)

Project status

- ☐ ongoing
☐ finished

Funding source

- ☐ EU - H2020
☐ EU - FP7
☐ EU (other)
☐ National
☐ Industry
☐ Self-funded
☐ Other:

Objective of the project (native language)


1

Please enter up to 300 words.

Objective of the project (in English)

1

Please enter up to 300 words.


Description of the context


Please enter up to 300 words.

Figure 1: Survey questions for projects


2.4.2 Survey for scientific articles


The survey contains some questions that are specific for the scientific articles (Figure 2). We asked for the title, author(s), source (eg. journal), year of publication and the Digital Object Identifier (DOI).


General - Identity



What is your SFT?

☐ Product
☐ Project
☒ Article

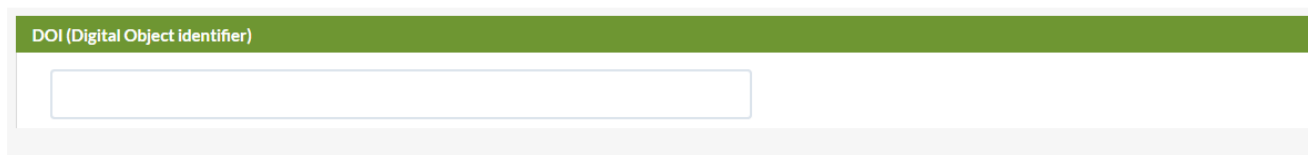

Title of the article


Author(s)


Source (Journal / proceeding)


Year of publication

 Your answer must be between 1950 and 2017
 Only an integer value may be entered in this field.



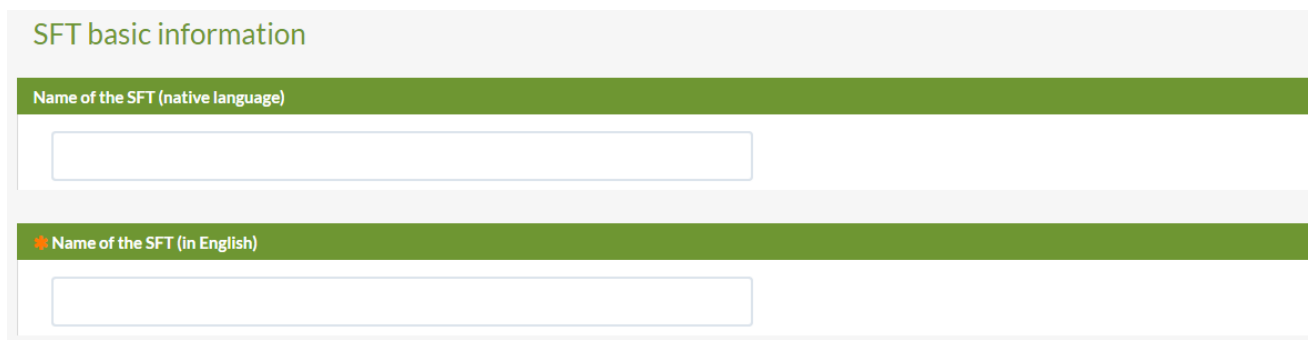
DOI (Digital Object identifier)

Figure 2: Survey questions for articles

2.4.3 Basic information

After questions that were specific for the type of entry (scientific article or project), some basic information questions were asked about the SFT.

The survey basic information starts by asking to give up a general name for the SFT (Figure 3). This can also be done in a native language, so users will have the option of reading information in their own language.



SFT basic information

Name of the SFT (native language)

★ Name of the SFT (in English)

Figure 3: Name of SFT

We then asked about keywords that affiliate with the SFT (Figure 4). These keywords give a good general impression on what this SFT is about. The SFT can be about the agricultural production system, so this keyword can be chosen when the SFT is about the actual agricultural system, (e.g. weed suppression in organic farming, farming practice, how to navigate on the field). Another keyword is about the equipment and machinery that is used in the field, mainly for SFTs with technical features. The SFT can be about plant production and horticulture specific crop growth elements. They can also be specifically designed for targeting fertilization, soil management and/or functionality, water management, climate aspects, energy management and the management of waste by-products and residues. A specific keyword was also added for the management of biodiversity and nature as a SFT

goal. Lastly, SFTs can be about farming/forestry competitiveness. The option was given to provide five additional keyword to properly describe the SFT in term of keywords.

Please check the keywords that describe your SFT?
 ⓘ This question is mandatory
 ⓘ Please check at least one item.

<input type="checkbox"/> Agricultural production system	<input type="checkbox"/> Water management
<input type="checkbox"/> Farming practice	<input type="checkbox"/> Climate and climate change
<input type="checkbox"/> Farming equipment and machinery	<input type="checkbox"/> Energy management
<input type="checkbox"/> Plant production and horticulture	<input type="checkbox"/> Waste, by-products and residues management
<input type="checkbox"/> Fertilisation and nutrients management	<input type="checkbox"/> Biodiversity and nature management
<input type="checkbox"/> Soil management / functionality	<input type="checkbox"/> Farming/forestry competitiveness and diversification

Please give up to 5 additional keywords that describe your SFT

Figure 4: Keywords characterizing the SFT

The geographical location where the SFT is intended to be used was retrieved systematically via the entry of EIP-AGRI NUTS regions (Figure 5). A link was provided to give more detail on what this is about to the survey applicant. For situations in which a region did not meet the classification properly, an open field on the geographical location was provided.

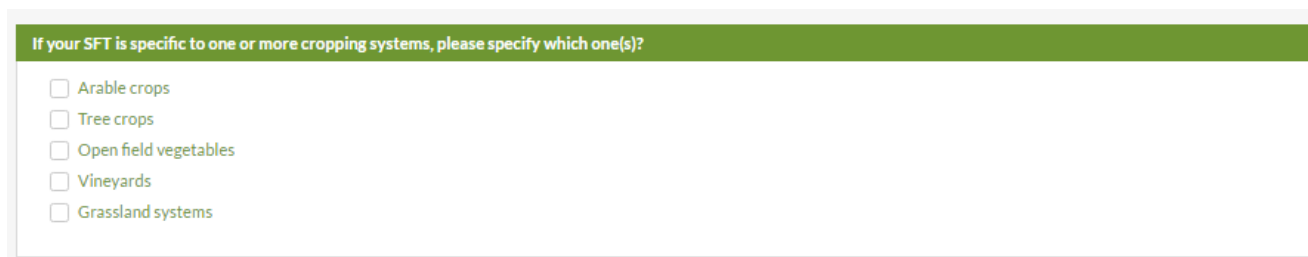
Please refer to the Eurostat NUTS classification to indicate where this SFT is intended to be used.

ⓘ Please visit [Eurostat NUTS classification website](#).
 Structure your answer using the following examples:
 EU = SFT is used in all or most of Europe
 FR = SFT is used in all of France
 FR5 = SFT is used in France NUTS-1 region 5 ("Ouest")
 FR52 = SFT is used in France NUTS-2 region 52 ("Bretagne")
 FR524 = SFT is used in France NUTS-3 region 524 ("Morbihan")
 Two or more regions may be indicated as follows:
 FR, NL22, NL321

Other geographical location

Figure 5: Geographical classification of the SFT

SFTs are expected to be specific to one or a few of five major cropping systems: arable crops, tree crops, open field vegetables, vineyards and grassland systems (Figure 6). Applicants were asked to check one or multiple boxes.

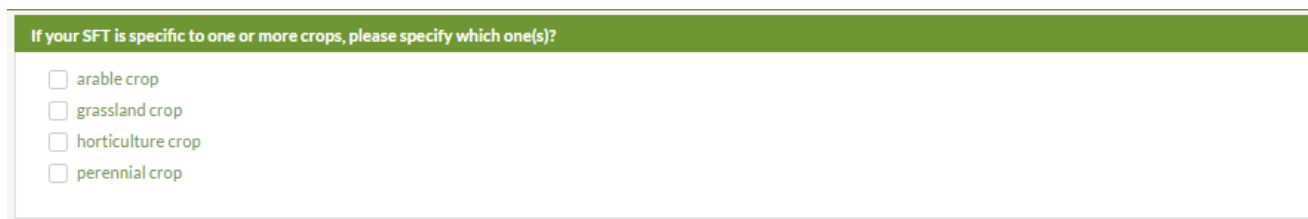


If your SFT is specific to one or more cropping systems, please specify which one(s)?

- ☐ Arable crops
- ☐ Tree crops
- ☐ Open field vegetables
- ☐ Vineyards
- ☐ Grassland systems

Figure 6: Cropping System where the SFT is used

A similar question was added for the type of crop with which the SFT could be dealing (Figure 7). We distinguished between arable crops, grassland crops, horticultural crops and perennial crops. It was also possible to indicate the exact crop in a new box that appears after filling out this question.



If your SFT is specific to one or more crops, please specify which one(s)?

- ☐ arable crop
- ☐ grassland crop
- ☐ horticulture crop
- ☐ perennial crop

Figure 7: Specific crop for the SFT

A few field operations can be chosen namely: tillage, sowing, transplanting, fertilization, pesticide application, weed control, pest- and disease control, irrigation, harvesting, post-harvest storage¹ and the scouting of crop, for example in the situation of field data retrieval (Figure 8). The option to include another field operation was provided in the “other” box.

¹Post-harvest activities should not have been included in the survey considering an earlier decisions on the scope of the SFT's to include. This field operation was therefore not included in the analysis.

In what kind of field operations is this SFT meant to be used?

ⓘ This question is mandatory
 ⓘ Please check at least one item.
 ⓘ If you choose 'Other,' please also specify your choice in the accompanying text field.

<input type="checkbox"/> tillage	<input type="checkbox"/> pest and disease control
<input type="checkbox"/> sowing	<input type="checkbox"/> irrigation
<input type="checkbox"/> transplanting	<input type="checkbox"/> harvesting
<input type="checkbox"/> fertilization	<input type="checkbox"/> post-harvest storage
<input type="checkbox"/> pesticide application	<input type="checkbox"/> scouting of crop and/or soil
<input type="checkbox"/> weed control	<input type="checkbox"/> Other: <input type="text"/>

Figure 8: Field operation for this SFT

It was considered important to retrieve some information on the person that is expected to use the specific SFT (Figure 9). This could be a farmer, contractor (including consultants), supplier, buyer of farm products or a processor of farm product.

Who will use the SFT?

ⓘ This question is mandatory
 ⓘ Please check at least one item.

☐ Farmer

☐ Contractor

☐ Supplier

☐ Buyer of farm products

☐ Processor of farm products

Figure 9: User type of the SFT

All SFTs have a Technology Readiness Level (TRL) (Table 1), meaning that they fall in to different categories of “readiness” for use (Figure 10).

How close to the market is this technology? (TRL - Technology Readiness Level)

Patent status

Figure 10: Technology Readiness Level of the SFT

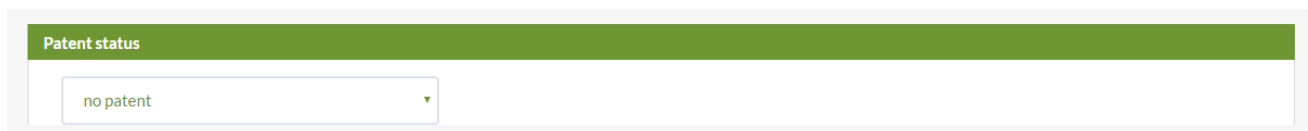
The first level (TRL1) means that only basic principles have been observed, meaning that the SFT is just available on a conceptual level with or without a research plan. The second level (TRL2) stands for ‘technology concept formulated’, so on this level the SFT is assumed to have a clear conceptual basis. The third level (TRL3) assumes a ‘experimental proof of

concept' meaning that the SFT is proven to be of interest in for example a lab setting. The fourth level (TRL4) goes one step further by stating that the SFT is actually validated in a lab. The fifth level (TRL5) assumes validation in a more relevant environment, for example in a test field. The sixth readiness level (TRL6) assumes that the technology is actually demonstrated in a relevant environment. The seventh level (TRL7) assumes there is a prototype that has been demonstrated in a relevant environment. The eighth readiness level (TRL8) means that we have a complete system that is also qualified for the job that was targeted. The last, ninth level of technological readiness (TRL9) assumes that the entire actual system is proven to be effective in the operational environment, meaning the environment in which the SFT will be used.

Table 1: Technological Readiness Level (TRL)²

TRL (Technology Readiness Level)	
1	Basic principles observed
2	Technology concept formulated
3	Experimental proof of concept
4	Technology validated in lab
5	Technology validated in relevant environment
6	Technology demonstrated in relevant environment
7	System prototype demonstration in operational environment
8	System complete and qualified
9	Actual system proven in operational environment

It was considered relevant to know if there is any patent on the SFT (Figure 11). There could be no patent, the patent could be pending, submitted, expired or in-force. If no information was available the answering box can be left blank.



The image shows a web form with a green header bar labeled "Patent status". Below the header is a white rectangular box containing a dropdown menu. The dropdown menu is currently open, showing the text "no patent" in green, with a small downward-pointing arrow to its right.

Figure 11: Patent of the SFT

²https://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf

A final question in this category presents a box in which a link to other websites can be provided that could be of relevance for clarification of the basic information on the SFT (Figure 12).

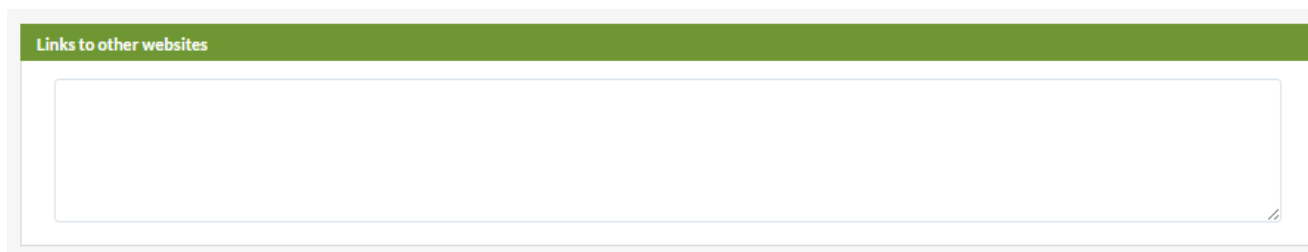
The image shows a screenshot of a survey form. At the top, there is a green header bar with the text "Links to other websites" in white. Below this header is a large, empty rectangular text box with a thin blue border, intended for users to provide links to other websites. The entire form is set against a light gray background.

Figure 12: other websites relevant to the SFT

2.4.4 Details

The last section of the survey consists of questions about the detailed information of the SFT.

A large box in the survey was used to get a detailed description of the SFT (Figure 13). An option to answer in a native language was also provided. After this a question was asked on the objective of the SFT, in order to find out what this SFT was actually set out to achieve.

SFT details

Description of the SFT (native language)

Please enter up to 300 words.

Description of the SFT (in English)

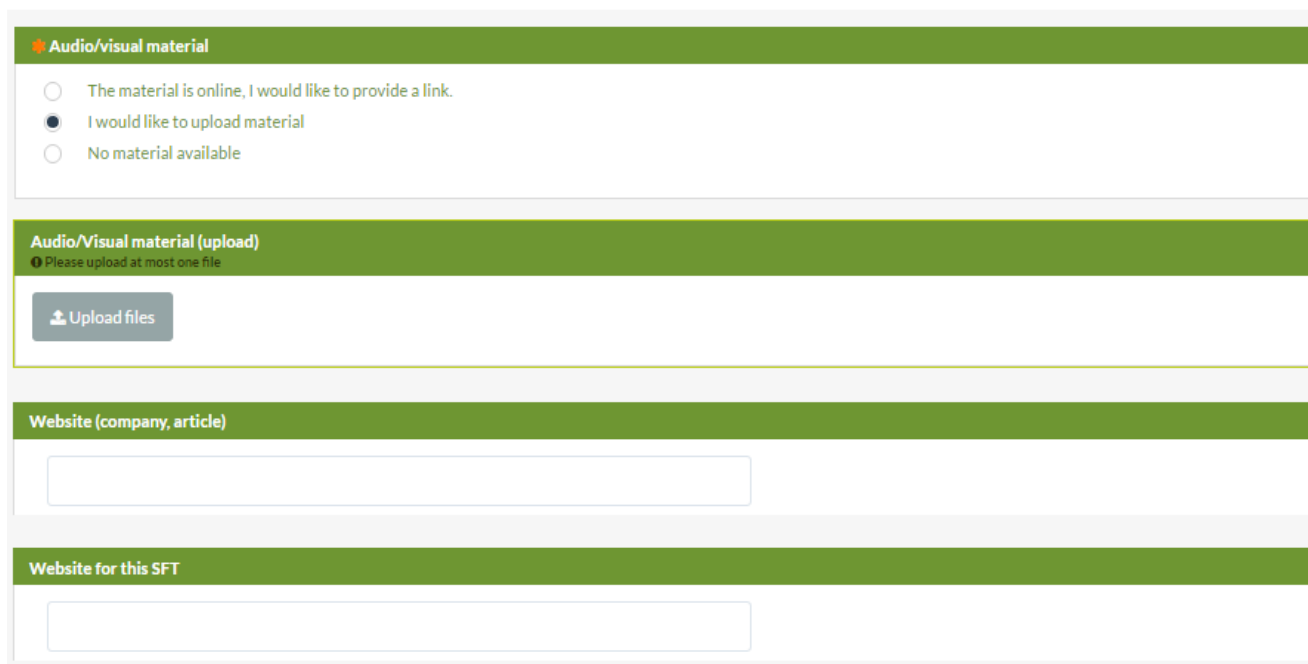
Please enter up to 300 words.

Objective of the SFT

Please enter up to 300 words.

Figure 13: Description and objectives of the SFT

An option is provided to add audiovisual material on the SFT if this is available (Figure 14). A link could be provided as well as a direct upload. We also asked for relevant webpages of the SFT company that may be involved or just a general SFT web page.



Audio/visual material

☐ The material is online, I would like to provide a link.
☒ I would like to upload material
☐ No material available

Audio/Visual material (upload)
 Please upload at most one file

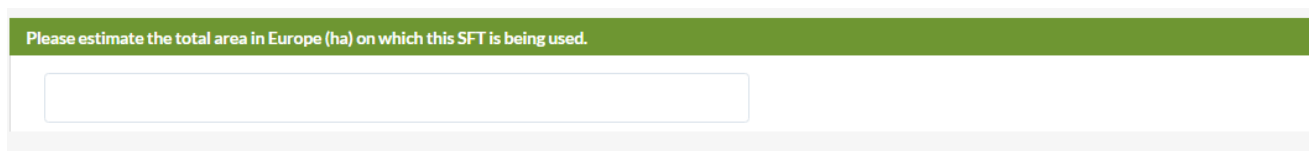
Upload files

Website (company, article)

Website for this SFT

Figure 14: Audiovisual material for the SFT

To be able to estimate the current applicability of the SFT, we asked to give an indication of the total area in Europe in which this SFT is used (Figure 15).



Please estimate the total area in Europe (ha) on which this SFT is being used.

Figure 15: total area in Europe where this SFT is used

A large box is included to find out more about the effectiveness of the SFT (Figure 16). Effects were expected on 26 possible critical subjects: productivity (crop yield per ha), the quality of a product, revenue-, profit and farm income, soil biodiversity, biodiversity (other than soil), input costs, variable costs, post-harvest crop wastage, energy use, emissions of CH₄, CO₂, N₂O, NH₃ and NO₃, the use of fertilizer and pesticides, irrigation, labor time, stress and fatigue, the amount of physical labor, number and severity of accidents, number and severity of accidents resulting in spills, property damage or the incorrect application of fertilizers and pesticides, pest residue on products, weed pressure, pest pressure (insects) and disease pressure from for example bacteria and fungi. Effects could be expressed using a scale ranging from a large decrease up to a large increase. An open checkbox provided

the possibility to supplement this scale with relevant percentages, providing the option to give an even more precise indication of the effects of the SFT when this is possible.

✱ This SFT has the following effect on:

	Large decrease	Some decrease	No effect	Some increase	Large increase	If possible, please quantify percentage of change
Productivity (crop yield per ha)	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Quality of product	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Revenue, profit, farm income	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Soil biodiversity	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Biodiversity (other than soil)	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Input costs	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Variable costs	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Post-harvest crop wastage	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Energy use	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
CH4 (methane) emission	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
CO2 (carbon dioxide) emission	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>

N ₂ O (nitrous oxide) emission	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
NH ₃ (ammonia) emission	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
NO ₃ (nitrate) leaching	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Fertilizer use	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Pesticide use	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Irrigation water use	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Labor time	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Stress or fatigue for farmer	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Amount of heavy physical labour	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Number and/or severity of personal injury accidents	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Number and/or severity of accidents resulting in spills, property damage, incorrect application of fertiliser/pesticides, etc.	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Pesticide residue on product	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Weed pressure	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Pest pressure (insects etc.)	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Disease pressure (bacterial, fungal, viral etc.)	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>

Figure 16: Effectiveness of the SFT

In order to find out more on what kind of SFT is presented a yes/no checkbox was included asking to check on whether the SFT is a recording/mapping technology, a reacting/variable rate technology, a guidance/ controlled traffic farming technology, a farm management information system/application or a robotic system/smart machine (Figure 17).

★ This SFT is a:		
	Yes	No
Recording or mapping technology	<input type="radio"/>	<input type="radio"/>
Reacting or variable rate technology	<input type="radio"/>	<input type="radio"/>
Guidance or Controlled Traffic Farming technology	<input type="radio"/>	<input type="radio"/>
Farm Management Information System application or App	<input type="radio"/>	<input type="radio"/>
Robotic system or smart machine	<input type="radio"/>	<input type="radio"/>

Figure 17: Kind of the SFT

Another relevant detail is the price of the SFT, this was included in a separate question (Figure 18).



Please indicate the price of this SFT (in local currency; please indicate currency)

🔔 In case the price is not defined, write NA.

Figure 18: Price of the SFT

The following question consisted of a few statements one could agree with or not, considering the relevance of the statement for the SFT (Figure 19). The check box included a scale ranging from strongly agree up to strongly disagree. The seven statements are:

1. *This SFT replaces a tool or technology that is currently used. The SFT is better than the current tool.*

This question is specifically aimed at SFTs than are aiming at creating added value over existing tools.

2. *The SFT can be used without making major changes to the existing system*

Some SFTs are expected to require more changes to the existing system than others.

3. *The SFT does not require significant learning before the farmer can use it*

The answer to this statement can give an indication on the learning effort that need to be made by the farmer. This can be useful information in order to compare the difference in learning requirements between different SFTs

4. *The SFT can be used in other useful ways than intended by the inventor*

Some SFTs may hold multiple purposes making them useful for the achievement of many very different effects.

5. *The SFT has effects that can be directly observed by the farmer*

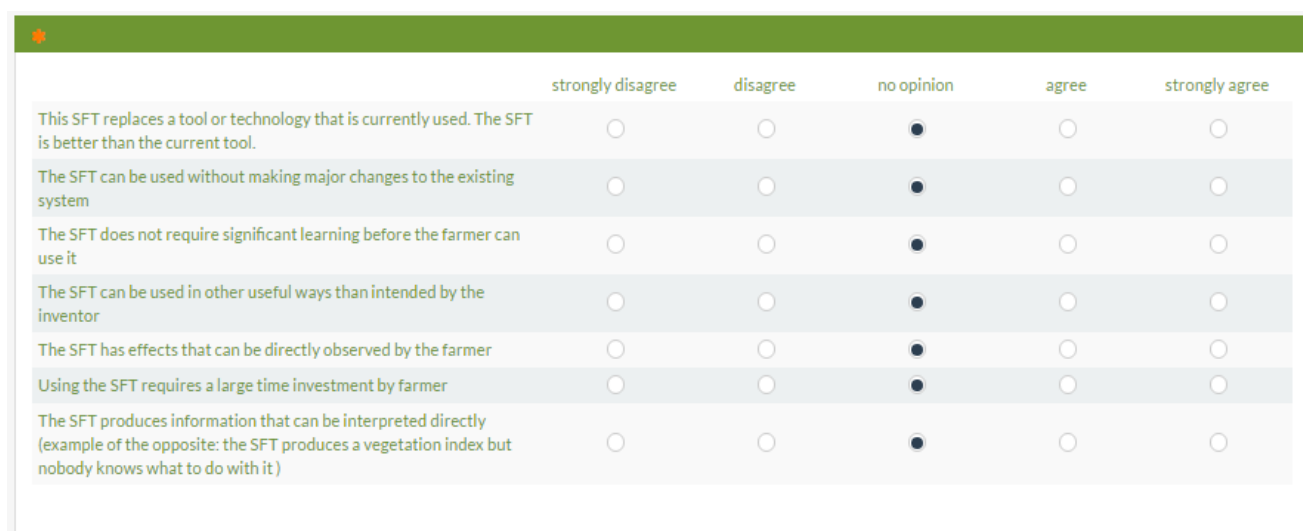
It is considered an advantage when effects can be directly observable by a farmer, because this will make it more likely that the farmer will find the SFT relevant for his/her situation.

6. *Using the SFT requires a large time investment by farmer*

The answer to this statement will give an indication on the time investment that is needed from the farmer in order to use the SFT. The time investment will play a role in how attractive the SFT is to use.

7. The SFT produces information that can be interpreted directly (example of the opposite: the SFT produces a vegetation index but nobody knows what to do with it)

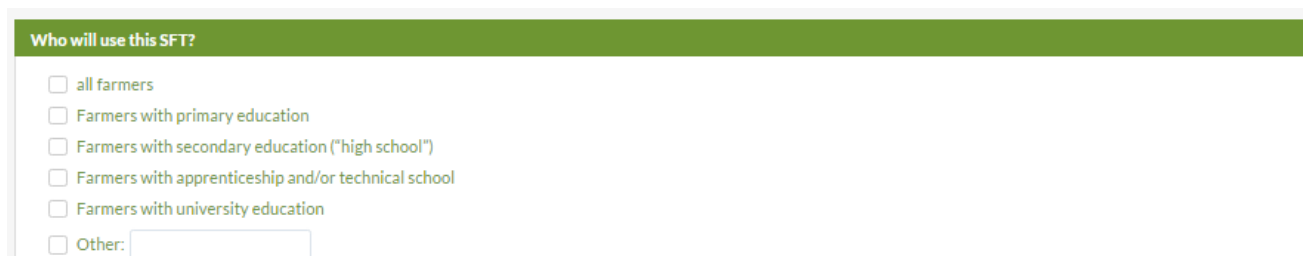
It is desirable when results are presented in such a manner that they are easy to interpret. This makes the results more interesting for end-user and results in consistency in the interpretation.



	strongly disagree	disagree	no opinion	agree	strongly agree
This SFT replaces a tool or technology that is currently used. The SFT is better than the current tool.	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
The SFT can be used without making major changes to the existing system	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
The SFT does not require significant learning before the farmer can use it	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
The SFT can be used in other useful ways than intended by the inventor	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
The SFT has effects that can be directly observed by the farmer	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
Using the SFT requires a large time investment by farmer	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
The SFT produces information that can be interpreted directly (example of the opposite: the SFT produces a vegetation index but nobody knows what to do with it)	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>

Figure 19: Statements regarding the SFT

The type of farmer that uses the SFT is considered, this can be all farmers, farmers with a primary education, farmers with secondary education, farmers with an education at a technical school and farmers with an university education (Figure 20). An open answering box was included to be able to enter other types of education, when this is necessary.

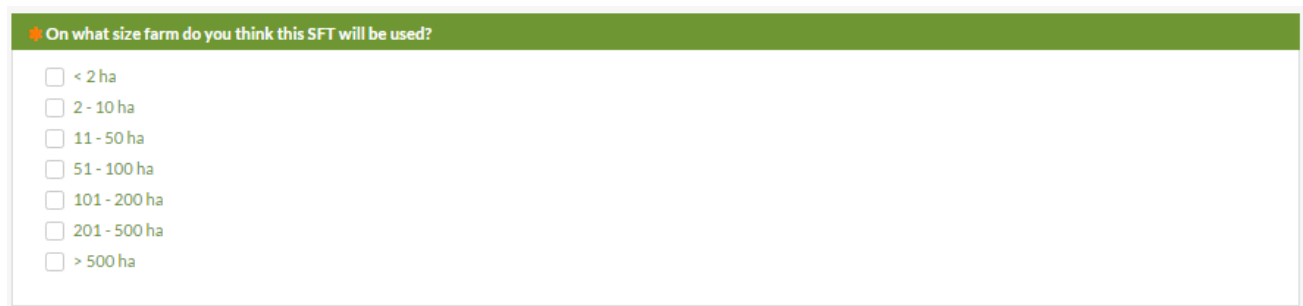


Who will use this SFT?

- ☐ all farmers
- ☐ Farmers with primary education
- ☐ Farmers with secondary education ("high school")
- ☐ Farmers with apprenticeship and/or technical school
- ☐ Farmers with university education
- ☒ Other:

Figure 20: User of the SFT

Another detail that has been included is the farm size, answering field ranges from less than 2 ha to more than 500 ha (Figure 21).

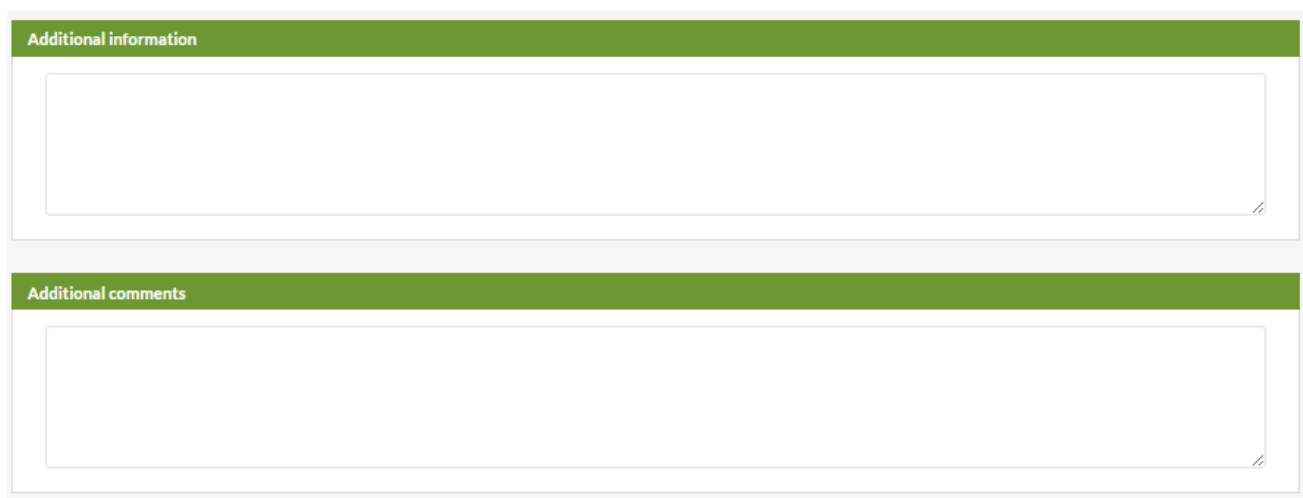


On what size farm do you think this SFT will be used?

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

Figure 21: Farm size to use the SFT

Finally, there is room for additional information and comments (Figure 22).



Additional information

Additional comments

Figure 22: Additional information on the SFT

2.5 Data entry and database development

The survey was used to enter data to a database, that facilitates further analysis. Where possible we used the article abstracts to fill in our questionnaire. If the abstract was not conclusive, we studied the papers to fill in the questionnaire. The database was continuously updated when new information was added.

3 Results

3.1 Survey entries

The total amount of survey entries is 1103. Of this number we have 718 scientific articles and 201 research projects that have been filled in by universities and research institutes. adding up to a total amount of 919 research projects results entries. Other entries (164) consisted of products that are available on the market, this was filled in by industry. The remaining 20 entries were erroneous. There is a difference in the amount of entries for each question, not all questions had an equal amount of replies.

3.2 SFT development

The amount of articles being published on SFT is growing very fast. Each year more publications arrive that meet the criteria of SFT (Figure 3.1). This indicates an increased interest in the development of SFT.

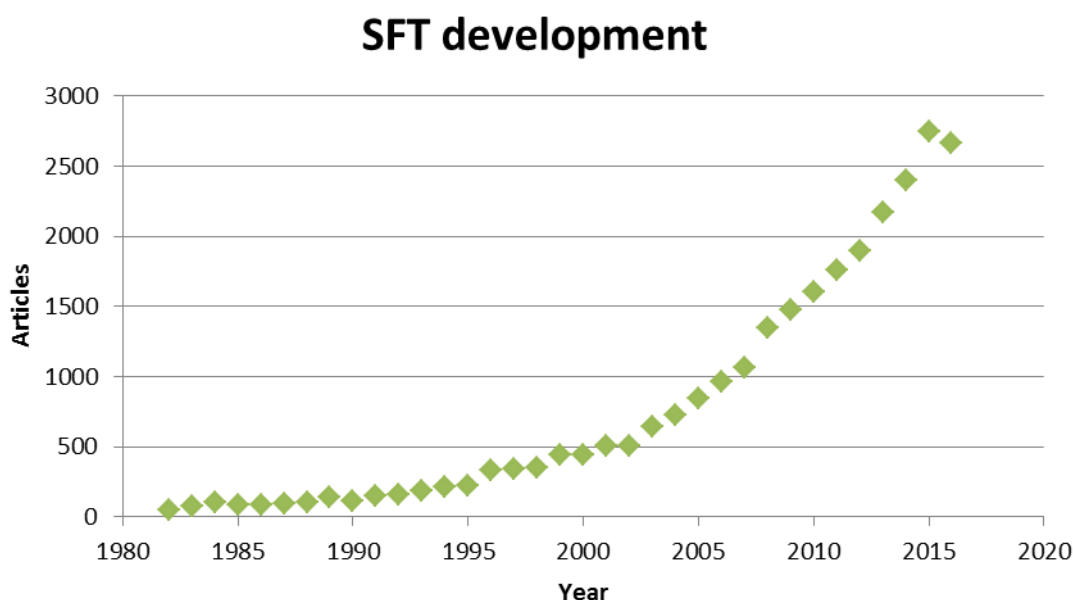


Figure 23 Number of articles per year that are found with the Scopus query. Data for 2016 are incomplete.

3.3 Types of SFTs

The questions on basic information and details explain characteristics that help identify the type of SFT. The following sectors will summarize results that help understand what different types of SFT are present.

3.3.1 Technology readiness levels

Table 2 presents the differences in technology readiness level (TRL) between the scientific articles and research projects. Nine different levels for technology readiness have been distinguished ranging from a project or article addressing just basic principles (TRL1) up to a system that has thoroughly been proven to work in the relevant operational environment (TRL9). Most technologies are in the stage where they are validated in a relevant environment.

Table 2: Technological Readiness levels

TRL (Technology Readiness Level)		Scientific articles	Research projects
1	Basic principles observed	2	0
2	Technology concept formulated	4	3
3	Experimental proof of concept	19	10
4	Technology validated in lab	62	3
5	Technology validated in relevant environment	175	30
6	Technology demonstrated in relevant environment	35	11
7	System prototype demonstration in operational environment	94	18
8	System complete and qualified	8	2
9	Actual system proven in operational environment	11	11
Total		410	88

3.3.2 Types of SFT

Different types of SFT can be distinguished (Table 3). In the situation of scientific articles most entries are directing toward farm management information systems in the form of a system application.

Table 2: Types of SFT

	Type of SFT	Scientific articles	Research projects
1	Recording or mapping technology	35	224
2	Reacting or variable rate technology	10	66
3	Guidance or Controlled Traffic Farming technology	7	21
4	Farm Management Information System application or App	50	95
5	Robotic system or smart machine	16	67

3.3.3. Field operations

The results for different field operations are summarised in Table 4. In the scientific articles the scouting of crops and/or soil is a very well represented subject. The best represented subject in the case of the projects is fertilisation, which is also a large subject in the scientific articles that have been selected.

Table 3: Field operations

	The field operation in which the SFT is used	Scientific articles (Yes)	Research projects (Yes)
1	Tillage	17	12
2	Sowing	4	14
3	Transplanting	2	12
4	Fertilisation	64	31
5	Pesticide application	31	15
6	Weed control	48	12
7	Pest and disease control	43	20
8	Irrigation	60	27
9	Harvesting	32	25
10	Post-harvest storage*	3	4
11	Scouting of crop and/or soil	189	26
12	Other	**	**

*This option was excluded later on because it was decided to limit our results to operations before harvest, but excluding post-harvest operations.

**Sometimes there was no specific field operation applicable. Examples are: Navigation, safety, forestry, communication technology and crop rotation.

The keywords that are most relevant for our sample of SFTs are presented in Figure 24 and 25. The keywords for scientific articles are mostly about farming equipment and machinery, the farming practise and agricultural production system. These keywords are very often combined with other keywords, such as plant production and horticulture, fertilisation and nutrients management, water management and soil management and functionality. The other keywords related to farming/forestry competitiveness, biodiversity and nature management, waste by-products and residues management, energy management and climate and climate change where also considered relevant but were chosen in fewer entries.

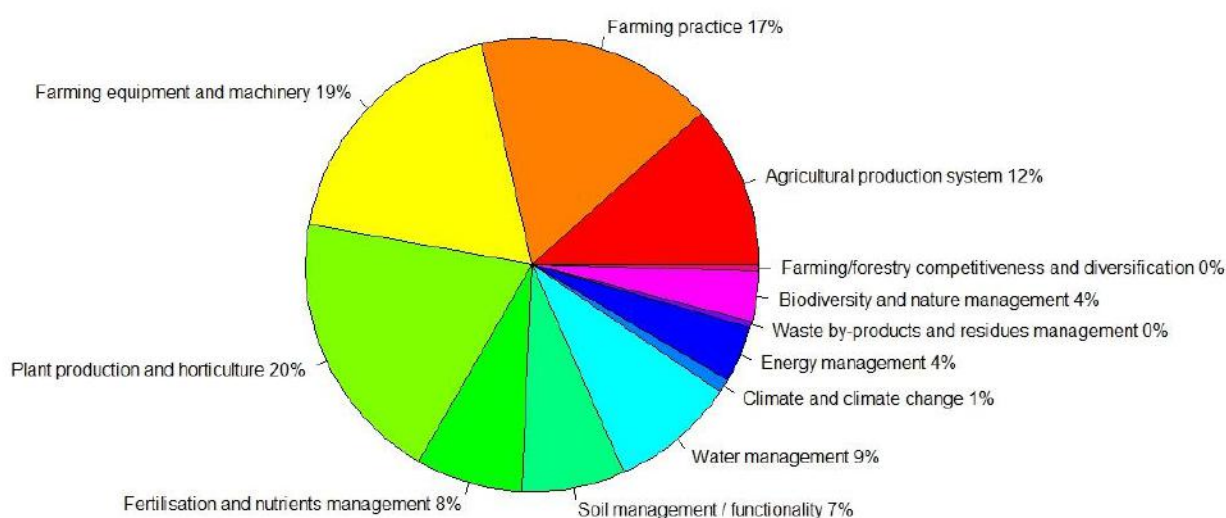


Figure 24: Keywords for scientific articles (incl. rounded %)

In the case of research projects equipment and machinery, farming practise and plant production and horticulture are also the keywords that were considered relevant in most cases, however fertilisation and soil- and water management were slightly more important when compared to the entries for scientific articles.

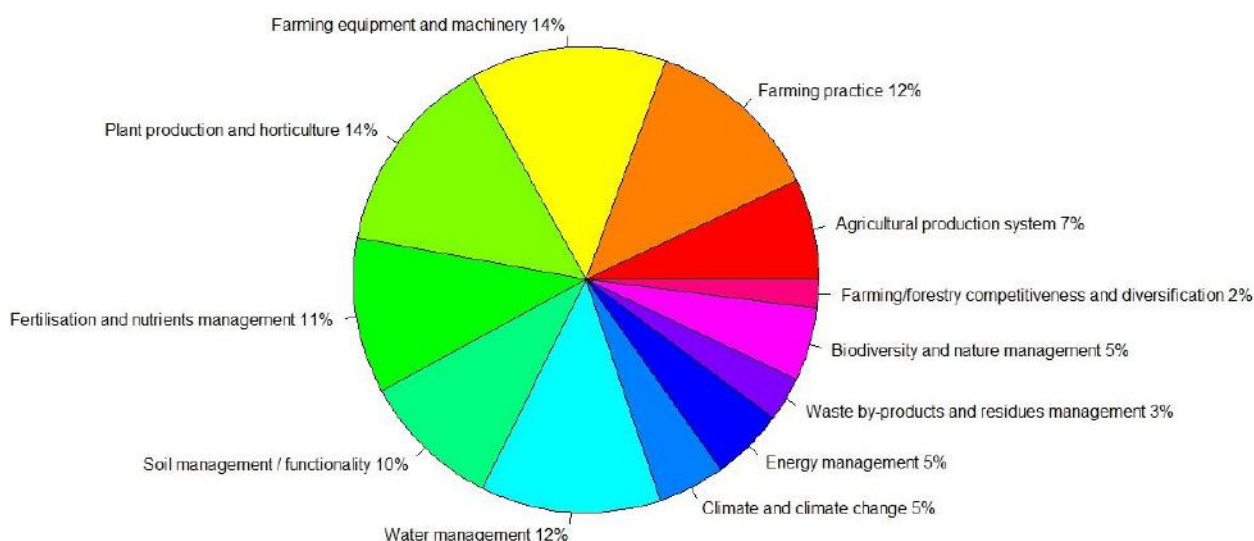


Figure 25: Keywords research projects (incl. rounded %)

3.4 Application of SFTs

Apart from different types of SFT we also found many variations in the applicability of SFTs. Most of the SFTs are applicable to the entire area of Europe. In the case of the scientific articles and research projects no specific regions were entered.

3.4.1 SFT application general

Six statements on the application of the SFT could be filled in by level of agreement (Table 5). 409 scientific article entries and 86 research project entries were given in total for this question.

40% of the scientific article entries replace an already existing technology. Mostly, this does not require major changes to the existing system. The question on the amount of learning that is required before a farmer can use the SFT is answered mostly with disagreement, meaning that often significant learning is required. In many situations there is more than one application to a SFT and the effects of the SFT can be observed directly by the farmer. SFTs

do not often require large time investments from the farmer and the information that is being produced can be observed directly.

60% of the research project SFTs replace an existing tool or technology. In most cases no major changes to the existing system are required. Many SFTs require significant learning before it can be used by a farmer. SFTs have multiple effects that can be directly observed by the farmer. In most cases no large time investments are required from farmers in order to get familiar with SFTs. SFTs often produce information that can be used directly.

Table 5 statements on application

Application statement		SD	D	A	SA	NO
Scientific Articles						
1	This SFT replaces a tool or technology that is currently used. The SFT is better than the current tool.	1	8	162	18	220
2	The SFT can be used without making major changes to the existing system	1	49	74	5	280
3	The SFT does not require significant learning before the farmer can use it	9	133	97	17	153
4	The SFT can be used in other useful ways than intended by the inventor	0	17	98	12	282
5	The SFT has effects that can be directly observed by the farmer	0	79	124	2	204
6	Using the SFT requires a large time investment by farmer	5	106	84	0	214
7	The SFT produces information that can be interpreted directly (example of the opposite: the SFT produces a vegetation index but nobody knows what to do with it)	6	98	106	5	194
Research Projects						
1	This SFT replaces a tool or technology that is currently used. The SFT is better than the current tool.	1	0	52	19	14

2	The SFT can be used without making major changes to the existing system	0	1	35	3	47
3	The SFT does not require significant learning before the farmer can use it	0	31	27	6	22
4	The SFT can be used in other useful ways than intended by the inventor	0	6	34	5	41
5	The SFT has effects that can be directly observed by the farmer	0	6	37	10	33
6	Using the SFT requires a large time investment by farmer	5	40	4	0	37
7	The SFT produces information that can be interpreted directly (example of the opposite: the SFT produces a vegetation index but nobody knows what to do with it)	0	4	34	20	28

SD = Strongly disagree, D = Disagree, A = Agree, SA = Strongly Agree, NO = No Opinion

3.4.2 SFT users

The users of SFTs are mostly expected to be contractors (Table 6), this category includes advising stakeholders, like consultants. Suppliers are next in the list. Very few of the selected SFTs are expected to be used by buyers of farm products and processors of farm products.

Table 6: Users of SFTs

	Who will use the SFT	Scientific article	Research projects
1	Contractor	333	53
2	Supplier	28	25
3	Buyer of farm products	17	7
4	Processor of farm products	21	8

The effects on 26 different agronomic aspects for the scientific article entries are presented in Table 7.

Table 7: Effects reported for scientific articles

The SFT has an effect on		No effect	Large decrease	Some decrease	Some increase	Large increase
1	Productivity (crop yield per ha)	286	0	0	119	4
2	Quality of product	354	0	0	54	1
3	Revenue, profit, farm income	213	0	2	190	4
4	Soil biodiversity	368	0	2	38	1
5	Biodiversity (other than soil)	384	0	0	24	1
6	Input costs	340	1	67	1	0
7	Variable costs	351	2	56	0	0
8	Post-harvest crop wastage	367	0	41	1	0
9	Energy use	262	6	140	1	0
10	Variable costs	408	0	1	0	0
11	CO ₂ (carbon dioxide) emission	403	0	6	0	0
12	N ₂ O (nitrous oxide) emission	404	0	5	0	0
13	NH ₃ (ammonia) emission	402	1	6	0	0
14	NO ₃ (nitrate) leaching	399	1	9	0	0
15	Fertilizer use	360	3	45	1	0
16	Pesticide use	374	4	31	0	0
17	Irrigation water use	353	12	44	0	0
18	Labor time	279	12	115	3	0
19	Stress or fatigue for farmer	256	7	146	0	0
20	Amount of heavy physical labour	395	0	14	0	0
21	Number and/or severity of personal injury accidents	404	2	3	0	0
22	Number and/or severity of accidents resulting in spills, property damage, incorrect application of fertiliser/pesticides, etc	341	20	48	0	0
23	Pesticide residue on product	390	1	18	0	0
24	Weed pressure	368	5	36	0	0
25	Pest pressure (insects etc.)	388	1	20	0	0
26	Disease pressure (bacterial, fungal, viral etc.)	384	7	18	0	0

Many of the selected scientific articles show decreased negative effects and increased positive effects. Increases are expected in productivity and quality of products. The articles indicated an increase in revenues, profits and/or farm income and opportunities for an increase in (soil) biodiversity could be seen. All negative effects were expected to be mitigated at least a few times. Expectations are largest for energy use and relief of labor and stress for farmers.

Table 8: Scientific projects

The SFT has an effect on		No effect	Large decrease	Some decrease	Some increase	Large increase
1	Productivity (crop yield per ha)	22	0	1	51	12
2	Quality of product	28	0	0	52	6
3	Revenue, profit, farm income	15	0	0	58	13
4	Soil biodiversity	57	0	0	25	4
5	Biodiversity (other than soil)	62	0	0	23	1
6	Input costs	35	1	49	1	0
7	Variable costs	28	1	54	3	0
8	Post-harvest crop wastage	36	12	38	0	0
9	Energy use	39	4	43	0	0
10	Variable costs	64	3	19	0	0
11	CO ₂ (carbon dioxide) emission	57	4	25	0	0
12	N ₂ O (nitrous oxide) emission	69	2	15	0	0
13	NH ₃ (ammonia) emission	69	1	16	0	0
14	NO ₃ (nitrate) leaching	64	3	19	0	0
15	Fertilizer use	35	9	42	0	0
16	Pesticide use	48	4	34	0	0
17	Irrigation water use	38	12	36	0	0
18	Labor time	28	5	53	0	0
19	Stress or fatigue for farmer	30	5	51	0	0
20	Amount of heavy physical labour	60	1	25	0	0
21	Number and/or severity of personal injury accidents	71	3	12	0	0
22	Number and/or severity of accidents resulting in spills, property damage,	60	5	21	0	0

	incorrect application of fertiliser/pesticides, etc					
23	Pesticide residue on product	55	2	29	0	0
24	Weed pressure	52	2	32	0	0
25	Pest pressure (insects etc.)	50	2	34	0	0
26	Disease pressure (bacterial, fungal, viral etc.)	44	4	38	0	0

In the case of the research projects (Table 8) increases are also expected in productivity and quality of products. The articles indicated an increase in revenues, profits and/or farm income and opportunities for an increase in (soil) biodiversity could be seen. Negative effects were expected to decrease in all cases. Decreases are most often seen in variable costs and relief of labor and stress for farmers.

There was no large variation in farm-size found (Table 9), most SFTs are reliant on very small or very large farms. In the case of scientific articles more articles were found that preferably are applied a somewhat smaller farmsize.

Table 9: Farm size

Farm size (ha)		Scientific article	Research projects
1	<2	303	67
2	2-10	306	71
3	11-50	311	76
4	51-100	368	78
5	101-200	283	73
6	201-500	271	72
7	500>	254	69

4. Conclusions

Attention for Smart Farming is increasing. SFT development through time has shown a steady increase in the amount of scientific articles published on smart farming each year. Several conclusions can be drawn about the types of SFTs that were found and the aspects involved in the applicability of the SFT.

4.1 Types of SFT

Research papers and projects were found to be mostly validated in a relevant environment, however only few research entries show SFTs that are actually proven in the relevant operational environment.

The vast majority of research projects is about recording or mapping technologies, to get more information on agronomic variables in the field. In the case of research articles more entries are about farm management information systems or apps.

There are several field operations that SFTs are used for. Most SFTs are focussing on the scouting of crops and soils. Irrigation and fertilisation are also very important topics.

When we consider the keywords that help classify SFTs a similar focus is seen for the research articles and projects. SFTs are often classified as machinery related or focussing on the farming practise or production system. Plant production, fertilisation and water- and soil management are also considered very important. Less often SFTs were qualified as focussing on farming/forestry competitiveness, biodiversity and nature conservation, waste by-products and residue management, and energy and climate.

4.2 Application of SFTs

The application of SFTs is similar for research articles and research projects. Many entries replace an already existing technology. Mostly, this does not require major changes to the existing system. Significant learning is often required for the correct application of SFTs. In many situations there is more than one purpose or application to a SFT and the effects of the SFTs can be observed directly by the farmer. SFTs do not often require large time

investments from the farmer and the information that is being produced can be observed directly.

Regarding the application of SFTs, contractors were most often identified as the most likely users of SFTs. Buyers of farm products were identified as users only very few times.

Application of SFTs often brings an increase in revenue, a reduction in stress and labour time for the farmer and a reduction in energy use. A reduction in costs, both variable- and input costs, was also often expected by the implementation of SFTs. There were also some improvements expected regarding environmental aspects.

There was a slight tendency toward average farm sizes for the application of SFTs.

SFT is in continuous development, it was seen that there is a tendency toward the scouting of crops and soils with information technology solutions. Regarding the application of SFT, research SFTs are often building on existing technology. Although significant learning is required this does not often lead to large time investments for farmers. The results of SFT are easy to observe. Both revenue and environmental aspects are of great importance in SFT development in the research sector.

Acknowledgements

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APPENDIX I Queries

Projects selection query

```
SELECT * FROM eu_projects
```


```
WHERE (lower(eu_projects.objective) ~~ '%sensor%':text OR lower(eu_projects.objective)
~~ '%automat%':text OR lower(eu_projects.objective) ~~ '%decision-support%':text OR
eu_projects.objective ~~ '%dss%':text OR lower(eu_projects.objective) ~~
'%database%':text OR lower(eu_projects.objective) ~~ '%ict%':text OR
lower(eu_projects.objective) ~~ '%autonom%':text OR lower(eu_projects.objective) ~~
'%robot%':text OR lower(eu_projects.objective) ~~ '%gps%':text OR
lower(eu_projects.objective) ~~ '%gnss%':text OR lower(eu_projects.objective) ~~
'%information system%':text OR lower(eu_projects.objective) ~~ '%image analysis%':text
OR lower(eu_projects.objective) ~~ '%image processing%':text OR
lower(eu_projects.objective) ~~ '%precision agriculture%':text OR
lower(eu_projects.objective) ~~ '%smart farming%':text OR lower(eu_projects.objective) ~~
'%precision farming%':text) AND (lower(eu_projects.title) ~~ '%agricult%':text OR
lower(eu_projects.title) ~~ '%crop%':text OR lower(eu_projects.title) ~~ '%arabl%':text OR
lower(eu_projects.title) ~~ '%farm%':text OR lower(eu_projects.title) ~~ '%vineyard%':text
OR lower(eu_projects.title) ~~ '%orchard%':text OR lower(eu_projects.title) ~~
'%horticult%':text OR lower(eu_projects.title) ~~ '%vegetabl%':text);
```

Scopus query

```
(TITLE-ABS-KEY(sensor or decision-support or dss or database or ict or automat* or
autonom* or robot* or gps or gnss or "information system" or "image analysis" or "image
processing" or "precision agriculture" or "smart farming" or "precision farming")) and (TITLE-
ABS-KEY(agricult* or crop* or arabl* or farm* or vineyard or orchard or horticult* or
vegetabl*)) AND ( LIMIT-TO(PUBYEAR,2001) ) AND ( LIMIT-TO(DOCTYPE,"ar" ) OR
LIMIT-TO(DOCTYPE,"re" ) ) AND ( LIMIT-TO(SUBJAREA,"AGRI" ) OR LIMIT-
TO(SUBJAREA,"ENGI" ) )
```

APPENDIX II Survey

Mapping of Smart Farming Technologies



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Please register to complete this survey.
Enter your details below, and an email containing the link to participate in this survey will be sent immediately.

Your name

SFT title

Email address (we will send you a link to the survey to this address)

Continue

Mapping of Smart Farming Technologies

Exit and clear survey


Smart Farming Thematic Network

Mapping of Smart Farming Technologies

Aim of Smart AKIS:

Smart-AKIS is a European Network mainstreaming Smart Farming Technologies among the European farmer community. The project will collect existing knowledge related to Smart Farming Technologies and will produce easily accessible end-user material under the EIP-Agri common format. The project will also integrate the socio-economic aspects involved in the innovation processes and will bridge the gap between practitioners and research on the identification and delivery of new Smart Farming solutions fit to the farmers' needs.

Goal of this survey:

The goal of the project is mapping of relevant existing research results, projects and products all across Europe whose scope are Smart Farming Technologies. The Inventory of all collected Smart Farming Technologies will allow searching available categories of solutions, so the end-users can easily find and implement them in their working routine.

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Mapping of Smart Farming Technologies

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General - Identity

What is your SFT?

- ☒ Product
☐ Project
☐ Article

Is this the first time you are filling in this questionnaire?

Yes

No

Company name

Legal name of the company

Street name and number

✳ Postal code

✳ City

✳ Country

Please choose... ▼

✳ Number of employees

☐ 1 - 10

☐ 11 - 50

☐ 51 - 100

☐ 101 - 500

☐ 501 - 1000

☐ 1001 - 10000

☐ 10000+

✳ Establishment (month, year)

✳ Value proposition/ Unique selling points

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General - Identity

★ What is your SFT?

- ☒ Product
- ☐ Project
- ☐ Article

★ Is this the first time you are filling in this questionnaire?

☒ Yes☐ No

★ Company name

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General - Identity

What is your SFT?

- ☐ Product
- ☒ Project
- ☐ Article

Project name

Project coordinator

Coordinator's email address

Project partners

Enter no more than 90 partners. Once you fill in the existing field, a new empty field will appear. Please enter one partner per field.

Project period

Start of the project (year)

End of the project (year)

Project status

- ☐ ongoing
☐ finished

Funding source

- ☐ EU - H2020
☐ EU - FP7
☐ EU (other)
☐ National
☐ Industry
☐ Self-funded
☐ Other:

Total budget

i Only numbers may be entered in this field.

Final report

i Please provide a link to the final report.

Objective of the project (native language)

i

i Please enter up to 300 words.

Objective of the project (in English)

i

i Please enter up to 300 words.

Description of the context

Please enter up to 300 words.

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General - Identity

What is your SFT?

☐ Product

☐ Project

☒ Article

Title of the article

✱ Author(s)

✱ Source (Journal / proceeding)

✱ Year of publication

ⓘ Your answer must be between 1950 and 2017
ⓘ Only an integer value may be entered in this field.

DOI (Digital Object identifier)

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SFT basic information

Name of the SFT (native language)

★ Name of the SFT (in English)

★ Please check the keywords that describe your SFT?

ⓘ This question is mandatory

ⓘ Please check at least one item.

- | | |
|---|---|
| <input type="checkbox"/> Agricultural production system | <input type="checkbox"/> Water management |
| <input type="checkbox"/> Farming practice | <input type="checkbox"/> Climate and climate change |
| <input type="checkbox"/> Farming equipment and machinery | <input type="checkbox"/> Energy management |
| <input type="checkbox"/> Plant production and horticulture | <input type="checkbox"/> Waste, by-products and residues management |
| <input type="checkbox"/> Fertilisation and nutrients management | <input type="checkbox"/> Biodiversity and nature management |
| <input type="checkbox"/> Soil management / functionality | <input type="checkbox"/> Farming/forestry competitiveness and diversification |

Please give up to 5 additional keywords that describe your SFT

★ Please refer to the Eurostat NUTS classification to indicate where this SFT is intended to be used.

Please visit [Eurostat NUTS classification website](#).

Structure your answer using the following examples:

EU = SFT is used in all or most of Europe

FR = SFT is used in all of France

FR5 = SFT is used in France NUTS-1 region 5 ("Ouest")

FR52 = SFT is used in France NUTS-2 region 52 ("Bretagne")

FR524 = SFT is used in France NUTS-3 region 524 ("Morbihan")

Two or more regions may be indicated as follows:

FR, NL22, NL321

Other geographical location

If your SFT is specific to one or more cropping systems, please specify which one(s)?

- ☐ Arable crops
☐ Tree crops
☐ Open field vegetables
☐ Vineyards
☐ Grassland systems

If your SFT is specific to one or more crops, please specify which one(s)?

- ☐ arable crop
☐ grassland crop
☐ horticulture crop
☐ perennial crop

★ In what kind of field operations is this SFT meant to be used?

ⓘ This question is mandatory
 ⓘ Please check at least one item.
 ⓘ If you choose 'Other,' please also specify your choice in the accompanying text field.

- | | |
|--|---|
| <input type="checkbox"/> tillage | <input type="checkbox"/> pest and disease control |
| <input type="checkbox"/> sowing | <input type="checkbox"/> irrigation |
| <input type="checkbox"/> transplanting | <input type="checkbox"/> harvesting |
| <input type="checkbox"/> fertilization | <input type="checkbox"/> post-harvest storage |
| <input type="checkbox"/> pesticide application | <input type="checkbox"/> scouting of crop and/or soil |
| <input type="checkbox"/> weed control | <input type="checkbox"/> Other: <input type="text"/> |

★ Who will use the SFT?

ⓘ This question is mandatory
 ⓘ Please check at least one item.

- ☐ Farmer
☐ Contractor
☐ Supplier
☐ Buyer of farm products
☐ Processor of farm products

★ How close to the market is this technology? (TRL - Technology Readiness Level)

Please choose... ▼

Patent status

no patent ▼

Links to other websites

Mapping of Smart Farming Technologies

[Resume later](#) [Exit and clear survey](#) [Question index](#) ▾



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SFT details

Description of the SFT (native language)

1

Please enter up to 300 words.

Description of the SFT (in English)

1

Please enter up to 300 words.

Objective of the SFT

1

Please enter up to 300 words.

★ Audio/visual material

- ☐ The material is online, I would like to provide a link.
☒ I would like to upload material
☐ No material available

Audio/Visual material (upload)

📎 Please upload at most one file

📎 Upload files

Website (company, article)

Website for this SFT

Please estimate the total area in Europe (ha) on which this SFT is being used.



This SFT has the following effect on:

	Large decrease	Some decrease	No effect	Some increase	Large increase	If possible, please quantify percentage of change
Productivity (crop yield per ha)	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Quality of product	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Revenue, profit, farm income	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Soil biodiversity	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Biodiversity (other than soil)	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Input costs	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Variable costs	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Post-harvest crop wastage	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Energy use	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
CH ₄ (methane) emission	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
CO ₂ (carbon dioxide) emission	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>

D1.2 Research project results on SFT

N ₂ O (nitrous oxide) emission	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
NH ₃ (ammonia) emission	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
NO ₃ (nitrate) leaching	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Fertilizer use	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Pesticide use	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Irrigation water use	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Labor time	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Stress or fatigue for farmer	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Amount of heavy physical labour	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Number and/or severity of personal injury accidents	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Number and/or severity of accidents resulting in spills, property damage, incorrect application of fertiliser/pesticides, etc.	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Pesticide residue on product	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Weed pressure	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Pest pressure (insects etc.)	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>
Disease pressure (bacterial, fungal, viral etc.)	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="text"/>

★ This SFT is a:

	Yes	No
Recording or mapping technology	<input type="radio"/>	<input type="radio"/>
Reacting or variable rate technology	<input type="radio"/>	<input type="radio"/>
Guidance or Controlled Traffic Farming technology	<input type="radio"/>	<input type="radio"/>
Farm Management Information System application or App	<input type="radio"/>	<input type="radio"/>
Robotic system or smart machine	<input type="radio"/>	<input type="radio"/>

Please indicate the price of this SFT (in local currency; please indicate currency)

❓ In case the price is not defined, write NA.

	strongly disagree	disagree	no opinion	agree	strongly agree
This SFT replaces a tool or technology that is currently used. The SFT is better than the current tool.	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
The SFT can be used without making major changes to the existing system	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
The SFT does not require significant learning before the farmer can use it	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
The SFT can be used in other useful ways than intended by the inventor	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
The SFT has effects that can be directly observed by the farmer	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
Using the SFT requires a large time investment by farmer	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
The SFT produces information that can be interpreted directly (example of the opposite: the SFT produces a vegetation index but nobody knows what to do with it)	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>

Who will use this SFT?

☐ all farmers
☐ Farmers with primary education
☐ Farmers with secondary education ("high school")
☐ Farmers with apprenticeship and/or technical school
☐ Farmers with university education
☐ Other:

On what size farm do you think this SFT will be used?

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

Additional information

Additional comments



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