EIP-AGRI Focus Group

Precision Farming

FINAL REPORT

NOVEMBER 2015

funded by European Commission

Table of Contents

funded by European Commission

Summary

The EIP-AGRI Focus Group on "Mainstreaming Precision Farming" brought together 19 experts, including scientists, farmers, advisers, and agribusiness to address current opportunities, limitations and transferable innovative solutions on the topic of Precision Farming. In particular, the EIP-AGRI Focus Group addressed **the main question** of **how to organise data capture and processing to mainstream the application of Precision Farming for input and yield optimisation, while trying to identify the main reasons behind the current lack of adoption, and identifying the key barriers to the implementation of Precision Farming on European farms.**

The group agreed that while data compatibility and management were important issues, there are also other fundamental barriers to adoption on EU farms. The utility of many Precision Farming applications has not yet been demonstrated. They also pointed out that Precision Farming needs the collaboration of all stakeholders for it to be widely adopted. The group therefore focused on why farmers would take up Precision Farming, the role of advisers, cost-benefit analysis and strategies for medium and small farm holdings, technical solutions and data management and compatibility and the role of public-funded research.

The EIP-AGRI Focus Group produced proposals to help mainstream Precision Farming throughout Europe:

1. Identification of key solutions which are already a success and can serve as examples;
2. Suggestions and proposals for specific actions and topics for Operational Groups (OG);
3. Recommendations for future research topics and methodologies.

Their recommendations included:

1. Farmers and cooperatives need to play a major role in innovation and in research on decision support systems and technical solutions to current problems. Overall technical solutions need to become smarter and integrated into farm management systems, to support farmers in their decision-making. The added value of these solutions should be tested, validated and demonstrated in practice on commercial farms representing different crops and geographic areas.
2. Independent advisers have a key role in mainstreaming Precision Farming and must be provided with appropriate knowledge, training and experience in Precision Farming, analytical support tools and training packages.
3. To assess the economic benefits of Precision Farming, scientifically reliable Precision Farming calculator tools need to be developed or adapted to take into account geographic regions, cropping and livestock systems and socio-economic variability across Europe. Furthermore, validated Precision Farming decision-support models and analysis tools need to be available for farm adviser and farmer trainings.
4. Precision Farming tools that are specifically designed for small and medium-sized farms are needed; these should be easy to use, affordable and robust.
5. Regional training and awareness are essential to reach advisers and small and medium-sized farms, as many farmers believe that Precision Farming is not profitable in small farms. Sharing and/or service contracting should be promoted in small and medium-sized farms (specifically for specialty high-value crop and livestock products) as an efficient route to adoption.
6. Much progress has been made in terms of technical solutions, but major steps are still required for the introduction and further development of i) electric drives to facilitate precise electronic control of equipment and implements; ii) Internet of Things to facilitate machine and processor communication; iii) nanotechnology and biosensors; iv) drones and autonomous platforms. Multidisciplinary approaches in R&D, co-creation and process efficiency are critical factors.
7. Technical solutions also need to be developed to generate 'as-applied' maps that can be combined with other data for making further management decisions.
8. New business models for data management are needed; sharing and open-data sources should be developed to bring Precision Farming to the next level. The recognition of data ownership is crucial. Portals that can facilitate the exchange of data are a prerequisite.

Farmer using his smartphone in the field, to follow up on cow welfare.

funded by European Commission

1. Introduction

Precision Farming refers to a management concept focusing on (near-real time) observation, measurement and responses to inter- and intra-variability in crops, fields and animals. Potential benefits may include increasing crop yields and animal performance, cost and labour reduction and optimisation of process inputs, all of which would increase profitability. At the same time, Precision Farming should increase work safety and reduce the environmental impacts of agriculture and farming practices, thus contributing to the sustainability of agricultural production. The concept has been made possible by the rapid development of ICT-based sensor technologies and procedures along with dedicated software that, in the case of arable farming, provides the link between spatially-distributed variables and appropriate farming practices such as tillage, seeding, fertilisation, herbicide and pesticide application, and harvesting. In livestock farming, it provides a link between animal-based variables and appropriate practices in relation to animal feeding, health, welfare, behaviour and production. In arable farming, the development of accurate positioning systems, principally Global Navigation Satellite Systems (GNSS), were the main enablers of 'precision'. In animal farming systems the electronic identification of individual animals through the development of low-cost wireless sensing systems, have enabled individual animal monitoring, for instance in dairy and pig husbandry, and in small groups in poultry.

In arable farming, Precision Farming has been relatively widely adopted by larger farms in Central and Northern Europe, the USA and Australia, where the main reason to adopt Precision Farming is to maximise profitability. In such conditions, straightforward Precision Farming applications such as Controlled Traffic Farming (CTF) and auto-guiding systems are the most successful applications, showing clear benefits in large-scale operations. When Variable Rate Application (VRA) approaches are used, inputs are applied in response to measured variability, and the main challenges are to understand and respond properly to such variability. In the case of fruit and vegetables and viticulture, new Precision Farming methods based on machine vision in combination with GNSS have demonstrated benefits through improved fruit quality as a key to obtaining a better market position. In Mediterranean agriculture intermittent periods of water scarcity make irrigation methods, and in particular Precision irrigation techniques, essential for good management in regions that are already under socio-economic pressure in agriculture.

In animal production, Precision Livestock Farming has enabled the automatic monitoring of individual animals and groups of animals for meat, milk and egg production control, as well as monitoring of animal behaviour, health and welfare, productivity and reduction of emissions. In the course of the past three decades, farms have greatly increased in size, and they have adopted highly automated processes for feeding, milking, egg collection and other tasks. For practical reasons, farmers manage groups of animals, but variability in performance has become an impediment to increasing economies of scale. By using modern information technology, Precision Livestock Farming allows farmers to record numerous attributes of individual animals, such as pedigree, age, reproduction, growth, health, feed conversion, killing-out percentage (carcass weight as percentage of live weight) and meat quality. Current milking technology in dairy allows aspects of cow health and fertility to be monitored. Alone or in combination, each of these measured attributes can be used to trigger an individual management response such as a feed change or a medical intervention. Individual animal monitoring with precise adjustments of feed and veterinary interventions through wireless systems are now in widespread use, with millions of monitor collars being sold annually within the EU. This approach reduces the use of antibiotics, as animals can be treated individually, reducing costs and risk. In pigs and poultry, most systems rely on a high degree of monitoring and control of ventilation, cooling and feed allocation to groups of animals, to ensure delivery dates and target weight.

In addition to economic goals, Precision Livestock Farming supports societal goals related to increasing food quality and safety. It can enable efficient animal farming which ensures sustainability through healthy animals with a low environmental footprint. Precision Farming plays a critical role in meeting the ever-growing demand for food, feed, and raw materials, while ensuring a sustainable use of natural resources and the environment.

funded by European Commission

There are currently a large number of sensors capable of collecting data for various applications, comprising soil and crop sensing, early warning systems for animal production, automatic lameness detection for cows and sows, etc.. The resulting large volumes of data need to be standardised, processed and integrated using metadata analysis, to generate useful input for decision-support systems. In this context, user-friendly IT applications need further development, as do accompanying measures to facilitate the mainstreaming of Precision Farming throughout the European Union.

The adoption of Precision Farming is challenged by differences in geographical location/climate, cropping systems, technical developments, social issues, diversity in field sizes and farm scale and diversity of farm and production-chain structures.

The EIP-AGRI Focus Group on "Mainstreaming Precision Farming" brought together 19 experts with different backgrounds and experience (scientists, farmers, advisers, etc.) to address current opportunities, limitations and transferable innovative solutions on the topic of Precision Farming. In particular, the EIP-AGRI Focus Group addressed **the main question** of **how to organise data capture and processing to mainstream the application of Precision Farming for input and yield optimisation, while trying to identify the main reasons behind the current lack of adoption, and identifying the key barriers to the implementation of Precision Farming on European farms.**

Although several benefits are attributed to Precision Farming technologies, barriers to their adoption across Europe still exist. This report is the result of the EIP-AGRI Focus Group (FG) on the topic of 'Mainstreaming Precision Farming', which was launched under the European Innovation Partnership 'Agricultural Productivity and Sustainability' (EIP-AGRI), to carry out the following tasks:

- Identifying and assessing the different systems and the use of data processing in Precision Arable Farming and Precision Livestock Farming
- Identifying and assessing where compatibility issues need to be resolved, and identifying potential solutions
- Identifying existing or potential solutions for processing large volumes of data from different types of Precision Farming sensors, as well as identifying existing or potential solutions for integrating these data into user-friendly farm management support systems
- Identifying existing or potential means of integrating Precision Farming systems into small and medium-sized holdings
- Identifying fail factors that limit the use of the techniques and systems by farmers; summarising how to address these factors, specifically exploring the role of innovation and knowledge transfer.

The group agreed that while data compatibility and management were important issues, there are also other fundamental barriers to adoption. The utility of many Precision Farming applications has not yet been demonstrated, due to deficits in user-oriented research at basic, applied and particularly cost/benefit analysis level, and due to a lack of technology transfer programmes and support resources that are necessary for business-driven innovation and market uptake. Precision Farming needs the collaboration of all stakeholders for it to be widely adopted.

funded by European Commission

The experts therefore decided to focus their discussions on the **empowerment of farmers** and the provision of better **support for advisers**, to overcome the perceived complexity of Precision Farming solutions. The topics of **cost-benefit** and **strategies in small and medium-sized farm holdings** were assessed by the experts, who focused on the challenges of demonstrating the profitability and utility on the medium-sized and small fields that are typical of Southern and some Eastern European regions. Other topics such as **technical solutions** and issues related to **data management and compatibility** for mainstreaming Precision Farming were identified as critical for its successful application, as the 'solutions' are normally a combination of hardware and software with appropriate implementation and data acquisition, storage and sharing. Finally, **needs for research** to boost innovation and knowledge transfer in Precision Farming were discussed.

Precision Farming refers to a management concept focusing on observation, measurement and responses to variability in crops, fields and animals. Benefits include increasing crop yields, cost reduction and optimisation of process inputs.

funded by European Commission

2. Results and recommendations

2.1. Why would farmers take up precision farming?

Some of the critical challenges to the successful and widespread adoption of Precision Farming in Europe are to overcome the investment risk, and perceived complexity of Precision Farming solutions and determine the specific benefits for the individual farmer. Risk, the initial investment required and insufficient knowledge appear to be the main reasons why farmers do not switch to precision farming. In addition, the utility of many precision farming applications has not been fully demonstrated, and the precision farming tools available may not be appropriate or sufficiently user-friendly.

A critical challenge to the successful adoption of Precision Farming is to overcome the investment risk and complexity of precision farming solutions.

State of play

Precision Farming's early promise in the 1990s failed to deliver successful solutions, leaving many farmers sceptical about many aspects of the technologies involved. While some technological aspects have been successfully marketed by the machinery industry and private companies, there is a need for 'independent' farm advisory support services.

Innovation process and fail factors

The innovation process in Precision Farming should concentrate on developing farm management solutions that are focused on today's farming reality and on perceived challenges for the majority of farmers. Solutions should be based on easy-to-use tools tailored to farm-specific situations. Several decision support systems and farm management information systems have been developed, or are being developed. These would require testing in different real farm situations. The FUTUREFARM project (see **Annex B**), for instance, integrates Farm Management Information Systems to support real-time management decisions and compliance to standards. The EU-PLF, PIGWISE, SILF (Smart, Integrated Livestock Farming), ROBOFARM and several other projects mentioned in **Annex B** also focus on developing decision support systems. The Precision Farming solutions provided should be intuitive and easy to understand. Specific Precision Farming tools and methods should also be developed for advisory services to support farmers. Innovation should aim to solve the problem of the high cost of some technological solutions currently available.

Needs for research

While there has been a strong research effort on Precision Farming in topics such as technical solutions and sensors, there are still significant research deficits which are limiting adoption by farmers. In particular, there is a lack of specific cost-benefit analytical tools, a failure to facilitate the input of farmers' knowledge to Precision Farming decision-support systems and to understand how farmers make management decisions, and an inadequate illustration of the potential environmental benefit of Precision Farming. To overcome these limitations, the Focus Group identified the following needs for research:

- A comparison of different decision support tools in precision farming, evaluating why they do or why they do not convince farmers.
- Developing an understanding of how farmers make decisions on a day-to-day basis and how including farmers in the development of Precision Farming technology and tools would maximise the use of their knowledge, resulting in systems that would be more readily adopted.
- Identifying ambassador farmers (and farms) as focus points for technology development and exchange, coupled with farmer-driven discussion group approaches. These groups should identify research and technology gaps, so key barriers and challenges can be addressed. Several projects and groups mentioned in **Annex C** and **Annex D** may provide inspiration, such as: 'Praktijknetwerken'; the project 'Koeien en Kansen' where 16 dairy farmers work together with researchers on increasing societal acceptance and sustainability; 'Boeren en Klimaat' - farmers working with researchers to improve their energy and CO_2 efficiency; the working group 'VarkensNet' where farmers take their practical problems

funded by European Commission

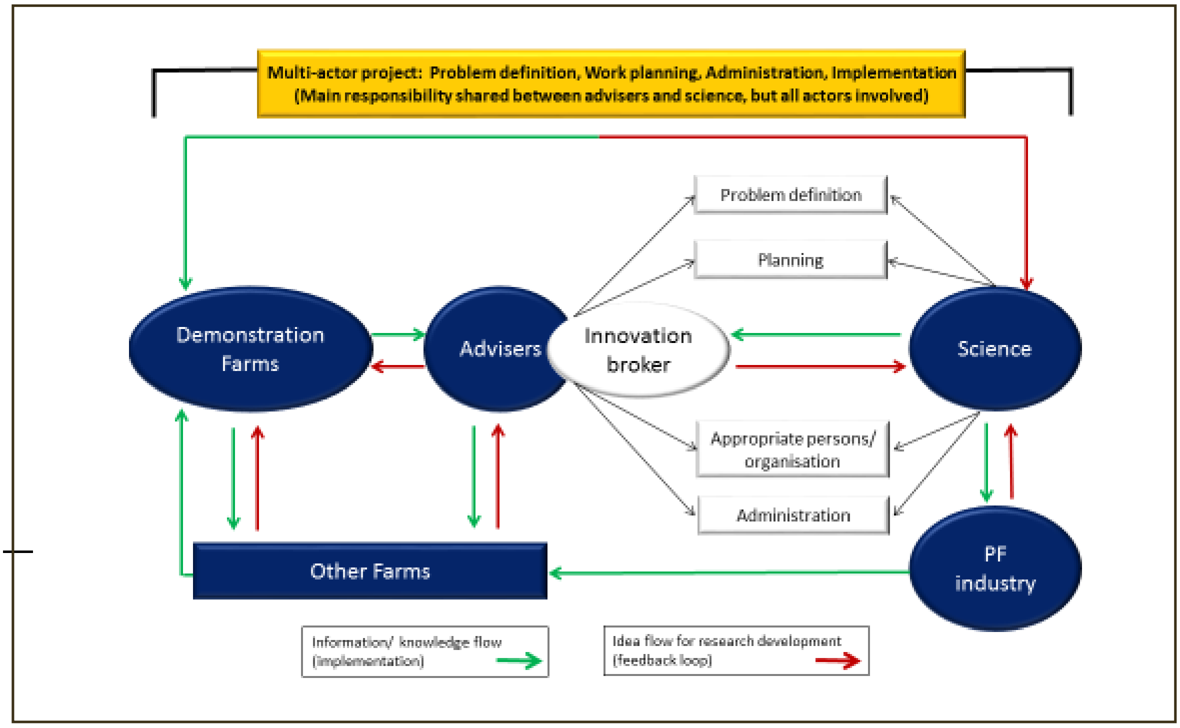
to researchers, who then launch a project and engage other private partners; and the project Cow Sensor which presents an online platform combined with workshops for farmers to exchange knowledge and experience on sensortechnology

- Understanding the causes of variation in crop production and animal performance to develop an appropriate management response resulting in more precise targeting of inputs/actions to optimise production. While this has been at the centre of precision farming since its inception, progress has been slow. Greater understanding of biological processes coupled with new and better sensors and improved data management are needed to progress this area. The Danish IPM – Plant protection project ('Etablering af/demonstrationsbrug') (**Annex C**) may provide inspiration for a research approach involving farmers: the farmer defines which Integrated Pest Management (IPM) principles are relevant after receiving advice on and seeing general IPM principles in practice on demonstration farms.

A multi-actor project as illustrated below, focused on Precision Farming extension and technology transfer has the potential to increase uptake of Precision Farming. The project's key aims would be to i) identify current technology transfer barriers to Precision Farming adoption; ii) develop improved farmer-focused technology transfer packages; iii) develop farmer-led and farmer-participatory extension programmes using ambassador farmers (and farms) and discussion group extension models; iv) focus on the identification of high-value Precision Farming solutions for farmers and realistic business potential for suppliers; and v) provide feedback where identified farmer/adviser needs would be communicated back to researchers and industry technology developers. The project would have farmer, adviser, industry and researcher members working collaboratively. Please see the figure below. Examples of such multi-actor research projects include PPP Precision Agriculture 2.0 (Netherlands) and Targeting Precision (Ireland), please see **Annex B**.

Farmers already using precision farming techniques can act as ambassadors.

Furthermore, research should investigate the positive effects of Precision Farming on environmental impact, for example by targeting fertilisers more accurately to the requirements, and preventing their application to more sensitive areas. This could result in a more efficient use of the input and a reduced risk of it leaching into water sources. INNO+ (EU), PPP Precision Agriculture 2.0 (Netherlands), and Precision Agriculture Sweden are some of the examples of existing research projects in this field, mentioned in **Annex B** and **Annex C**.



Recommendations and ideas for Operational Groups

Operational Groups related to technology and knowledge exchange involving farmers could concentrate on the following ideas:

- The development and implementation of Precision Farming data analysis and management tools.
- The development of appropriate tools such as web support/DSS systems,
- The development of appropriate Precision Farming implementation/support packages for different regions, cropping systems, livestock systems, scale of farms, and suitability for socio-economic regions. **Annex D** includes several examples that could provide inspiration, such as MecaOlivar, GreenVineyard, and Milkcontrol.
- Testing decision support tools in different real farm situations. The following projects, listed in **Annex B**, could potentially provide decision support tools to test: FUTUREFARM, EU-PLF, PIGWISE, Smart Dairy Farming SILF, and ROBOFARM projects. This will help identify barriers to adoption of these tools, and hopefully improve their usefulness.
- Clear cost-benefit (real business case) research to demonstrate the benefit of Precision Farming adoption in different scale/region/enterprise scenarios – allowing farmers to evaluate whether or not a certain technology could be worthwhile to adopt on their farm (also see **2.3**)
- The development of appropriate technical support for independent (public or private) advisory services to ensure that precision farming methods are delivered as part of an integrated farm management package.

2.2. Advisers

The role of advisers is crucial to successfully reach and support farmers, and promote the adoption of Precision Farming methods. Advisers can work in different roles, either as independent advisers providing knowledge on different systems or targeted advice (either privately or publically funded), or a public service such as improving resource efficiency and environmental benefits. They may also be linked to companies selling specific products and services, such as machinery and software. Below the advisers linked to specific companies are referred to as company consultants, and the focus of the recommendations in this report is on the independent advisers. Advisers need to understand Precision Farming, for them to transfer knowledge and experience to farmers.

The role of advisers is crucial to successfully reach and support farmers, and promote the adoption of Precision Farming methods.

State of play

Farm advisers play a central role in recommending, delivering and giving support to farmers on new technologies such as Precision Farming. The role of advisers is critical as they can be consulted by farmers as independent sources of knowledge and experience, rather than private company consultants whose role includes product sales in addition to support. In the past, advisers left Precision Farming technology transfer to private consultants tasked with marketing Precision Farming equipment or services. Occasionally independent advisers have advised against Precision Farming as they were unsure of its cost/benefit performance and perceived it as competition for their own services. However, Precision Farming has the potential to improve advisory services by improving management and the efficient use of resources, by facilitating more accurately targeted and improved management of crops and livestock on individual farms.

In some countries there is a lack of appropriate training for advisers, and as a result, professional skills and competences vary across the EU. As Precision Farming requires technical competence, a system of common certification for advisers across the EU would be desirable. A good example could be the Certificate for European Consultants in Rural Areas (CECRA) in German-speaking countries, which focuses not only on knowledge of

funded by European Commission

technology but also on advisory skills, developing modules for their training. A similar system expanded across the EU could help deliver Precision Farming competence among advisers.

To properly advise farmers on the adoption and use of precision farming tools, advisers need realistic information on the costs, benefits and technical challenges in real farm situations. A combination of research-based data management and analysis tools needs to be further developed and put into practice to enable advisers to easily manage, analyse and interpret Precision Farming data for use both on an individual farm basis and particularly in a benchmarking situation, where the benefits of the approach would be disseminated. In the project 'Precisielandbouw 2.0' advisers are also involved without being a specific target group. A network of applied research/innovation/demonstration projects would offer technology transfer support to advisers and growers.

Needs for research

While advisers need support from research to provide sound independent advice, the research needs are not specific to advisers, and they are therefore covered by the research needs in other sections of Chapter 2. The set-up of a web-based knowledge engine and wiki-type support portal system at EU level to support advisers in their daily work could be of interest.

Recommendations and ideas for Operational Groups

Farm advisers could play a positive role in Operational groups dealing with Precision Farming projects, but the topics for Operational Groups are not just relevant for advisers. They have therefore been covered under the other sections of this chapter, particularly the technology and knowledge exchange section 2.1.

2.3. Investment needs: Cost-benefit analysis of Precision Farming, and small and medium-sized farms

When farmers decide whether or not to adopt Precision Farming technology and methods, they will consider the profit and direct benefits for the farm. Currently farmers find it difficult to identify the potential benefits of implementing Precision Farming methods, sometimes due to the initial investment required. Investment needs for precision farming concern software, data sensors and accompanying software, and machinery. Some farmers fear that Precision Farming will bring additional costs and complexities, and new sources of technical problems. In small farms and farms with limited revenues, it will be especially difficult to clearly demonstrate the return on investment in Precision Farming. Precision Farming services could be offered either by larger neighbouring farms at lower cost or by companies as a service, or via other business models.

State of play

The benefit of current Precision Farming systems to the farmer is not always clear as investments required and actual reduction of inputs may not always be readily known. Some cost-benefit tools do exist but they are designed for specific scenarios, climatic conditions, and cropping systems. Also the information needed to calculate the economic benefits may be lacking. Other gains, such as social, and some environmental benefits, are difficult to quantify and probably mostly underestimated. More work is needed on assessing situations, areas, field sizes and conditions where Precision Farming would be profitable. Farmers with small fields and/or a small number of animals may question whether yield, soil mapping or individual animal data would add any useful new information for their management. Many smaller farmers would consider that precision farming technologies used by larger farmers would not be applicable to them. In summary, most farmers need a clear quantification of the potential benefits of Precision Farming before adoption is considered.

funded by European Commission

Innovation process and fail factors

Showing the benefits of specific precision farming technologies for each farm will require site-specific data. Computer simulation models / decision support systems that are easily accessible to farmers, advisers and researchers could be helpful. In addition to the availability of well-trained advisers, the models that are needed to test the potential benefits should be easy to use and based on genuine knowledge of the decision-making process in farming. Some existing examples of how this could be done are presented in Annex B and Annex D. The Sustainable Precision Fattening Pigs project resulted in a higher profitability at 2 pig farms, by optimising feed use and reduced nutrient excretion. In the Precision Agriculture School (precisionsskolan.se) the cost-benefit of variable rate-application of N, P and K and lime is calculated. In the EU-PLF project there is a specific workpackage that is focused on Value Creation. These tools and cost-benefit calculators should be developed for different scenarios and for a wide range of conditions to suit the heterogeneous conditions that exist across the EU. The Fitovid project (see Annex D) is a clear example of the use of new technologies and training to improve pesticide use in small vineyard farms.

When deciding on the adoption of Precision Farming technology and methods farmers look at the profit and direct benefits for the farm.

Typical fail factors include a lack of clear objective data to show the famer that the implementation of Precision Agriculture technologies will lead to higher income (profit and direct income for the farm), insufficiently trained Precision Farming advisers, and the lack of simulations / case studies for different scenarios. Farmers generally tend to identify Precision Farming as a set of tools that benefit only large holdings, both in crop and livestock production. This is linked to the perception of high costs and complexity of the production process and the new technology involved. To enable small farms to adopt Precision Farming technology, some innovation achievements and factors need to be met:

- Adoption of Precision Farming technology in small farms should be conducted in steps, reducing the level of complexity, to avoid large investments with higher risks at the beginning of the process.
- Initial solutions offered to small farms should be simple, affordable and robust.
- Establishing an accurate training and extension system can form a key to success.
- Stimulating robustness so that innovations for small holdings can be (re)applied in several sectors and farms, promoting the sharing of services and equipment.

Needs for research

Especially for small and medium-sized holdings, investment costs can severely limit a farmer's options to apply new innovative technology.
Research on low-cost /low capacity machinery and software could be of interest for the particular case of small/medium size holdings and technology providers. Similarly deployment methods such as service provision that does not require capital investment by individual farms, and the availability of accessible independent expertise need to be evaluated to support adoption on smaller sized units.

Recommendations and ideas for Operational Groups

There is a clear need for Operational Groups focused on the costs and benefits of Precision Farming, to determine the conditions, areas, cropping systems and socio-economic characteristics that affect the potential economic benefits for farmers. The Focus Group recommends exploring how the use of specific calculators could be extended throughout Europe. One example is the 'Be Precise Cost-Benefit Tool' of the UK Agriculture and Horticulture Development Board (HGCA), which estimates the potential economic benefit of Precision Farming technologies, particularly more accurate steering and machine control. This 'Precision Farming Calculator' is

funded by European Commission

currently available in the UK, and it enables a farmer to estimate the cost-benefits of Precision Farming adoption according to the nature of his/her farm and the specific Precision Farming system involved. In particular, such cost-benefit tools need to be further developed and should be expanded to livestock farming. The EU-PLF and the SILF projects (**Annex B**) may provide some useful input for this. The SILF project calculated the commercial/environmental benefit of the new systems along with 'object-connected ICT' through specific business models and lifecycle costing for farming systems. Impact assessments and cost quantification should be based on scientific methods such as cost- benefit, conjoint analysis or Return on Investment models, including Life-Cycle-Cost analysis. It is proposed to set up a representative demonstration/pilot farm environment comprising several farms and stakeholders (including researchers, IT experts, farmers, contractors, advisers) for the development, application, and EU-wide dissemination of a Precision Farming calculator tool.

Sharing services and equipment is one of the most directly applicable measures for the particular case of small farms. Investment in Precision Farming equipment can be reduced via joint purchase and sharing. Other options include the use of free, cheap or subsidised products such as remote-sensing and other spatial data services for small and medium-sized farmers. Such remote-sensing and other spatial data sets could be coupled with service providers working at small and medium-sized farms. Operational groups to test these different options in a regional setting, linking service providers (machinery, decision support systems and manpower), farmers and advisers could prove useful.

- Cost-benefit analysis of Precision Farming components and complete Precision Farming systems, including risk mitigation, across all enterprises.
- Develop robust methodologies for automatic decision and planning support systems, and model-based process control in Precision Arable and Livestock Farming. This includes optimal operating procedures for treating sick animals or crop diseases based on automatic early-warning systems which prevent economic losses. A better understanding of farmers' decision-making, conditions and methods is essential for this.
- Better quantify the actual benefits of different types of precision agriculture, including direct costs, indirect costs including work time, and physical and cognitive ergonomics (labour effects). The models used to determine the benefits should also include environmental benefits.
- Develop economic calculators for different cropping systems, geographical areas and socio-economic conditions within the EU.

Operational Groups on Precision Farming for small farms could be created, especially dealing with specific crops such as olives, vines, saffron, and for the particular cases of goats and sheep, turkeys, buffaloes for mozzarella cheese, since these have specific and different constraints compared to field crops. The following projects and groups may provide inspiration and inputs: USER-PA for horticulture and vines (**Annex B**); MecaOlivar for olives and Green Vineyard (**Annex D**). Specific ideas for such Operational Groups are:

- Developing Precision Farming best practices for small farm holdings/livestock, focusing on specific crops, and livestock systems.
- Developing and testing sustainable infrastructures for sharing machinery, software, hardware and advisory services among small and medium-sized farming operations.
- Adding value by using Precision Farming on short-chain produce in specialised products
- Developing simple, cheap and 'plug and play' devices; these will allow farmers to test the benefits and the interest of Precision Farming / Precision Livestock Farming in a simple and immediate way, without major investments.
- Developing methods and tools that require a small initial investment that can be directly applicable, minimising risk and ensuring profitability or alternatively facilitating Precision Farming contracting services.

2.4. Technical solutions

Technical solutions in precision farming need to become smarter and integrated into the farm management system to support farmers in their decision-making. Feedback from the farm needs to be incorporated to improve decision support systems. The integration of this smart technology, known as Precision Farming 2.0, helps farmers to lead their farms in the direction of sustainability, both environmentally and financially.

Young man fixing the rotor of Unmanned Aerial Vehicle (UAV) / octocopter (drone), to observe and map the field.

State of play

Precision Arable Farming and Precision Livestock Farming techniques attempt to determine and control all measures applied or inputs administered to farm land, crops and (individual) animals. These controlled farming techniques require advanced sensors to measure the current state of animals and land to optimise treatment of crops and livestock at the smallest scale. Several new sensors are available and new miniaturised instruments have been shown to be useful for mass data collection on the farm. Now farmers need cost-effective technical solutions that can be easily applied and integrated into the network of instruments deployed on the farm for a wide range of tasks and operations.

Innovation process and fail factors

Innovation will be accelerated by creating a framework in which farmers, cooperatives, extension professionals, scientists and the private sector can effectively collaborate and co-create knowledge. The goal is not only to involve farmers in the dissemination and the demonstration but also to give them an active role in the design, planning and implementation of agricultural research. Farmers are essential participants in the research process, to identify research priorities, to collaborate with scientists in conducting research, and to adopt and disseminate the results of research. This is why H2020 multi-actor projects are required to actively involve persons who will be using the research results in practice.

Innovation in technical solutions should facilitate farm administration and help the farmer to monitor sustainability (environmental and economic profitability). Technical solutions should allow farmers to produce more efficiently, leaving more time for managing, for instance through technical solutions for monitoring and controlling emissions. These solutions should enable farmers to show the quality, the sustainability and the safety of their product to consumers and policy makers.

Important potential fail factors for the integration of novel technical solutions into Precision Farming include the lack of open standards that lead to compatibility issues, and limited data-transfer bandwidths. Technical solutions should be user-friendly, and enable farmers to make the right management decisions and realise them reliably in the field, and include 'as-applied' data for sustainability reports. These solutions should come with a sound business model based on a clear demonstration of the costs and benefits for farmers. Their added value should be tested, validated and demonstrated in practice.

Needs for research

There is a need to ensure that the precision that is being targeted in Precision Agriculture systems is being achieved. There are currently deficits in data collection, mapping and machine control which hinder this process. Task maps define how the work should be done, while the 'as-applied' maps track whether the planned work was carried out correctly. Research is needed to develop technical solutions to generate realistic 'as-applied' maps, as these maps are critical for an understanding of crop uniformity and crop development, and to anticipate economic results. When these maps are correctly combined with other data (e.g. historical data) better and more precise management decisions will become possible.. Currently, these maps, like yield maps, are not sufficiently used by farmers because most of the necessary machinery is not yet ready to implement these technical solutions. They are not compatible with farmers' management information system (FMIS), or farmers are not aware that they exist. This is a general problem in many areas: farmers cannot re-use their own

funded by European Commission

information, often due to lack of knowledge. Progress is needed, so that electrically driven technical solutions can be used in the fields, instead of mechanical or hydraulic drive components, because they allow a much greater level of precision and control. Electrically driven technical solutions are considered to have important potential for application in Precision Farming. In particular, electric drives on implements are the next innovative step, and some examples of electrically actuated fertiliser spreaders are already available.

The Internet of Things (IoT), which is the interconnection of uniquely identifiable embedded computing devices within the existing Internet infrastructure, will make it possible to connect all devices that are available on the farm. Further research is necessary to enable sensors and farm equipment to communicate autonomously, with low cost and low energy use. Smart Farming is one of the domains where the Internet of Things could help develop initiatives that make use of new technological solutions, such as the Future Internet programme. New technology like Sigfox allows to continuously emit small amounts of data and already shows promising applications for the IoT like Stickntrack.
Recent advances in additive manufacturing (i.e. 3D printing) and low-cost, user-friendly electronics (e.g. Arduino) now allow small SMEs and farmers to build low-cost custom instrumentation for specific purposes. Research that combines wireless sensor networks and IoT can provide high-resolution spatio-temporal sensing data to monitor critical parameters in agricultural applications on real- or near-real time. Through the combination of technology and fast internet access, the farmer will have the results of remote sensing imagery collection (through drones or manned aircraft) on real time or just few hours after the acquisition in order to make decisions. A dairy farm in the United Kingdom is already running a 'connected' herd where the risks of epidemics could be anticipated and random factors in milk production could be spotted. This use of Big Data aims to revolutionise the sector (Meyer, 2013), however it requires a clear development focus as data on its own is of little value. The combination of wireless sensors and the future Internet in Precision Farming offers significant market potential, especially for SMEs.

Recommendations and ideas for Operational Groups

The Focus Group proposes the following ideas for Operational Groups that would help deliver a smarter agriculture by addressing the issues mentioned above. Yield maps can be used on different levels but currently few farmers actually use them. The Operational Groups should focus on making technical solutions smarter and more connected. Operational Groups dealing with issues related to prescription and as-applied maps are needed, to boost the use of technical solutions in Precision Farming. Initiatives on this particular topic should be expanded to establish new Operational Groups that would include relevant stakeholders. Existing initiatives are: ERANET ICT AGRI, PigWise, CowSensor, Interreg Smart Farming, Agritec Innovation System, eCow Users, The Modern Cow Barn Tecnology -project (NYT), and Group and Programme of Precision Farming (PPL) (see Annexes for descriptions and links to these initiatives).

Nanotechnology and biosensors are promising fields of interdisciplinary research which open up a wide array of opportunities in electronics and agriculture. However, we need biosensors that focus on useful applications at farm level, such as on-line progesterone detection in milk, eg ' Cowsensor' (**Annex C**). Operational groups could be a useful project format to develop these types of sensors, such as the ' Pig Cough Monitor'.

Finally, Operational groups could help unlock the potential of Unmanned Aerial Vehicles (UAV) and autonomous platforms. The challenge is to interconnect and interpret the 'big data' acquired by low-cost and efficient platforms to support decision-making. As an example, the combination of small sensors on board unmanned vehicles for fast turn-around times has been demonstrated in the FieldCopter project, where the farmer had access to the spatial products showing water and nutrient stress levels in grapes and potatoes a few hours after the drone had flown the field. Acceptance by the public, a legal framework to operate and a sound business model are all needed to further deploy this technology.

funded by European Commission

2.5. Data management and compatibility

The issue of data management and data compatibility forms one of the main current limitations to the wider spread of common tools and methods to handle data gathered by several sensors, approaches and temporal and spatial scales (Kempenaar, 2014). In particular, one of the main restrictions for data sharing among institutions, farmers, advisers and researchers is due to non-standard software and data formatting solutions. The challenge is to properly manage the large data sets that are acquired by different sensors, and to enable data sets to be shared easily, irrespective of the sensor model and brand used. As modern farms are increasingly loaded with all kind of sensors, data management, data storage, data sharing and interconnectivity strategies are urgently needed. The issue of data ownership must also be considered, as a clear legal framework for data ownership is important for further development in this area.

State of play

Most technology that is currently under development in research laboratories and companies is isolated not only from other research groups but also from standards designed by international organisations. Much of the software is initially written for specific projects which often lack formal software-developing standards. Systems are placed into farm environments where the connectivity is usually rather poor, and they are often not designed to share data even with other systems on the same farm. Hardware / software providers are not necessarily incentivized to share data with other systems as they strive to offer complete systems of their own. In addition to the difficulties in data management and data compatibility, it is often difficult to store the large amounts of data that are generated. Farmers, consultants, advisers, and related companies need a data infrastructure that can collect, store, visualise, exchange, analyse and use large amounts of data, and they require a legal framework to deal with the ownership and the use of data outside of the farm premises.

Innovation process and fail factors

Regarding data sharing and data management issues, enabling access to on-farm data sources would allow new business models to emerge from analysed data from several vendors. Data sharing may allow advisers to improve the quality of their advice, i.e. allowing them to provide services, with high accuracy, to groups of farms. Standard data formats would enable the development and articulation of new sensors that comply with data-format standards, not only permitting the interconnection of instruments and entire systems designed by different companies, but also preventing mistakes in their integration.

To handle large amounts of data, new methods are required that are based on the 'cloud', which provide solutions for issues such as data storage, data sharing, and data exchange. A major issue for data integration is the fact that different systems may be isolated due to a poor data communication on the farm or between farms. The ROBOFARM ICT AGRI project for instance integrates and harmonises existing software and hardware technologies into a technology platform, which can serve as e support system for farm level business decisions. A wireless connection (Wifi and 3/4G) can form a potential solution for data communication purposes. Previous experiences on innovative farms show that these techniques should be combined with high-broadband wired connections, to meet high peak capacity (for arable farming) and high reliability (e.g. for alarm systems). The ownership of data sets forms another critical aspect related to the massive amount of data that is gathered from sensors that are distributed across the farm. This has implications for data-sharing schemes and privacy issues. Farmers tend to be unwilling to share data about their operations with third parties, which poses serious problems regarding efficient data integration.

Data management and data compatibility issues form a major limitation to handling data gathered by several sensors, approaches and temporal and spatial scales.

Some innovative solutions that are under development or that are being tested in practice include:

- Farming in the cloud can replace storage devices such as USB sticks and flash cards, bypassing desktop PCs and in-house servers to use internet-based storage sites. Examples of existing programmes in **Annex D**: JDLINK, AGCOMAND, EASY, Farmpilot
- Methods to transfer data, especially for farms and areas with limited bandwidth and/or farms without internet access. In the USA, farmers can send their acquired data in a pre-paid UPS envelope to a high-speed upload centre for processing. Also new concepts such as Infobroker form the 'Smart Dairy Farming (**Annex B**)' project will stimulate data markets for sensor data, without having a need for large scale central databases.
- Client-server schemes vs. peer-to-peer connections
- The FIspace initiative employs FI technologies that permit a seamless collaboration in open, cross-organisational businesses
- The iGreen initiative (**Annex D**).

Regarding data compatibility issues, tools and protocols that allow systems to interconnect and that allow for data to be shared between different sensors and instruments have successfully been developed in other sectors. Innovation is required to agree on and decide on the standards that should be used. Europe has agreed on some data standards, for instance for animal ID in Precision Livestock Farming, but even within individual countries, holding numbers have different formats. An EU initiative is needed for technology suppliers and farmers to reach an agreement on data sharing, data formats, and protocols for inter-connection of systems and instruments.

Needs for research

The large number of sensors that is currently available provides vast data sets for different crop and livestock parameters. However, the decision support systems that can translate these data into useful information for the daily farm management are still insufficient. There is a serious disconnection between farmers' needs and the systems that are on offer.

The lack of cohesion in data exchange and the vendor lock-in scenario, which occurs even where a standard such as ISOBUS exists, limit the uptake of Precision Farming. Several standards are available, but these have been created by unrelated organisations and they are not centrally indexed. It is necessary to support initiatives that motivate farmers to invest in a common ICT infrastructure. Regulations regarding the ownership of data need to be developed, as in some cases farmers are afraid that data from their farm will be used 'against' their own interests. More research is needed to develop a user-centric cloud-based Farm Management System.

- Development of appropriate data management and analysis techniques for a range of enterprises and data types, including the interpretation of cross-linked data from different sources.

Recommendations and ideas for Operational Groups

In the field of data management, storage and sharing, initiatives have already been set up, such as EDI-Circle, Agro-EDI Europe, Smart-Agrimatics, ICT-AGRI with SILF Smart Integrated Livestock Farming and USER-PA, and Orange Smart Agri. UNIFARM coordinates a user forum with the aim of presenting and defending the needs of farmers in the development of GNSS applications and services. PPP Precision Agriculture 2.0 combines various topics. EDI-Circle is a cooperative effort of accounting firms, set up to promote the use and processing of already existing electronic data. New applications that have recently been developed include the Annual Nutrient Cycle Assessment, a tool that computes and presents farm and environmental performance at farm level. To extend the lifespan of cows the Smart Dairy Farming project developed the concept of Infobroker as a breakthrough where the data of each farm was released, to answer farmers' questions concerning nutrition, animal health and fertility.

Some examples of current activities on topics related to data access are GEOPORTAL (PF-related web open data platform with cadastral maps) and KTBL service (InfoAgrar = an infrastructure to the overarching analysis of data in Precision Livestock Farming).

funded by European Commission

Operational Groups may focus on the following ideas:

- methods for sharing data that support the application of Precision Farming to management of specific crops, feeding animals, or milking cows.
- Operational Groups connecting produce supply chain managers, sensor system suppliers and data aggregators with farmers, to ensure common standards for data files.
- Operational Groups focusing on human requirements for interfaces, meeting the needs of herdsmen.

It is essential to improve farmers' awareness of the benefits of owning their own data, demonstrate the benefits that benchmarking against other farms can bring, and stimulate owners of valuable data in the public sector to publish data for farmers. In the future the on farm data could become one of the farmer's main assets. It is necessary to spread the adoption of solutions ensuring common standards, thus promoting the interconnection of sensors and systems from different vendors, brands and models. The mechanism for this on the internet is the OASIS WS-I consortium, a non-profit coordinating body for web standards. Operational Groups could act as catalysts for European harmonization of Precision Farming / Precision Livestock Farming data and set standards for interoperability for approval by OASIS-WS-I. For example, data files for animal information should be specified in standard formats (XML, JSON) to include the unique animal identifier and a time stamp so that data about any given animal can be integrated into a continuous time series. A common terminology should be created of livestock events and crop events, in order to enable comparisons to be established.

2.6. Research to boost innovation and knowledge exchange in Precision Farming

State of play

Most European projects that are funded via public resources are performed by research institutes and universities. Most of them are really interesting but are far from the real situation of the primary production sector. Applied research activities that are connected to the agricultural sector and to real farms need to be boosted. In member states where public-private partnerships are promoted, we see an increase in commitment from the industry and a shift towards more applied research and a higher involvement of end users. It is also clear that involving the private sector in applied research will promote the spread of developments, which might increase the interest of different users. We therefore need farming research that has a closer connection to real, commercial farms, with a clear connection to farmers, instead of the traditional focus on laboratory activities.

Innovation process and fail factors

Most research in Precision Farming still concentrates on developing and testing sensor and sensing technology. Specifically in Precision Arable Farming key applications have focused on the use of sensor technology, in particular on the use of GPS location for tractors and the implementation of guidance systems. Data-gathering methods using innovative sensors have made tremendous progress, but decision-making that is based on collected data needs further research. Some of the challenges for innovation in the coming years are:

- A change in research attitudes is needed encouraging researchers to take into account farmers' opinions and advice. Research and product development both require an active interaction with farmers and other users of data and information that will be generated through Smart Farming. Projects need to embrace the idea of co-creation in both public and private partnerships. This will require projects and project funding that reward this type of research attitude.
- Innovation will be stimulated when it is not limited to the agricultural sector. Even within the agricultural domain, certain barriers still limit the exchange of ideas and of good innovation practices between sectors. In fact, major steps in innovation are expected to come from outside the agricultural sector. To stimulate innovation, awareness of developments should be increased, and agricultural specialists need to be encouraged to make these developments available for the agricultural and food sectors.

funded by European Commission

- Innovation is needed for the successful integration of research from different areas and sectors, in order to fulfil the requirements of organisations that need results to be transferred for a very diverse range of problems. A network of interdisciplinary Precision Farming researchers is needed. Innovation is also needed for the analysis and visualisation of real-time big data and artificial intelligence, and for translating those data into real-time decision-support advice and standard operating procedures.

Needs for research

Besides 'traditional' knowledge on the technological aspects of measuring techniques, on animal and plant behaviour and physiology, knowledge related to animal and plant diseases and basic ICT techniques that are needed to acquire, store and handle data, particular attention needs to be paid to the following points (see EIP-AGRI document on animal husbandry for further details related to Precision Farming and ICT techniques):

- Exploring products and services that can link data from precision farming field, stable or animal level right through to processed food and the whole value chain, and their economic possibilities. They can be valuable to help ensure food quality, and may also provide ways for farmers to receive a better price, for instance by proving that the food was sourced from farms which care for animal welfare and the environment.

- Precision Farming and Precision Livestock Farming are seen as a Smart Farming approach, where the focus lies on the implementation of products and services in real farming and chain practices. To study and help implement them, knowledge is needed on their sociological and economic impact, specifically their effect on business models and farming structures.

- Coordinated research actions among EU members should be organised, such as the ERANET ICT AGRI. These actions should have a focus on particular products. Potential targets include viticulture, horticulture, olive oil or fruit production in zones with special characteristics. In most cases, recent changes in EU legislation directly affect production activities, and most environmental aspects appear at the top of the list of productive factors. Research projects linked to those factors should be initiated.

Recommendations and ideas for Operational Groups

Current European Union-wide initiatives that have been created on the topics of Precision Farming and Precision Livestock Farming include the 'EU-PLF' and 'AllSmartPigs' projects, and at national level, specific networks like Smart Dairy Farming in the Netherlands. The creation of **Operational Groups** will improve farmers' awareness of the concept of Smart Farming. More specifically, some ideas for Operational Groups involving inter-regional Public-Private Partnerships include:

- Operational groups focusing on the implementation of Precision Farming in small productive areas and for Precision Farming mainstream activities. The HighResOrganic research project identified remote sensing solutions which could be integrated fully in organic farming and extended to all organic crops. And the project to find the most effective foliar fertilisers for organic farmers.

- Operational groups on remote sensing applications for agriculture, with a focus on nutrient management, disease detection, yield prediction. The BioSom research project aims to provide scientific support to detect soil-borne pathogens. The Agvance project focusses on new technologies to improve pesticide use in orchards and vineyards.

- Operational Groups or other projects on the potential applications of drones (Fieldcopter to deliver the right information in the right time on the right spot, developing a complete solution for UAS sensing) and unmanned systems in the context of Precision Farming are needed, to clarify the legal implications and the benefits of unmanned vehicles in agriculture.

funded by European Commission

2.7 Networking and dissemination

Across Europe there are large differences between regions in production potential, organisation of production chains and availability of workers, finance, service providers and technology providers. Knowledge and networks providing specific support to small and medium-sized farms could assist to support implementation in all these different situations.

The Focus group also pointed out that dissemination activities are very important to spread knowledge and experience in Precision farming, as this will help farmers to assess whether Precision farming would be worthwhile for them.

Regarding the **dissemination** of Precision Farming methods, technology and ideas the Focus group recommended:

- Precision Farming researchers and technology developers (ICT, sensors, equipment, etc.) must realise that it is essential that the technology developed is useful to farmers. Exchange with farmers on use and dissemination must be considered as a critical component of research projects.
- A pro-active approach towards advanced farmers, to launch articles and publications regarding proven Precision Farming solutions, customer experiences, on-going developments, research and other activities.
- Dissemination through 'ambassador farmers'. Examples from Annex D include the YARA/ POS programme where farmers are involved in testing up-coming PA-techniques for crop management; and Van den Borne aardappelen who tests and explains precision applications in everyday language.
- Dissemination through advisory services enabled by expertise/capacity building, for instance Ekotoxa and IPM - Plant Protection (Annexes C and D).
- Demonstration activities showing the use of precision farming calculators for different scenarios would provide farmers with a tool that can help them decide whether or not to implement Precision farming.
- Information campaigns through local extension magazines.
- Allowing new technology to be used before purchase.

funded by European Commission

3. Conclusions and Recommendations

The following list presents **the conclusions** of the Focus Group, on what needs to be solved to facilitate mainstreaming Precision Farming in Europe:

1. Farmers should be actively involved in the development of Precision Farming tools to ensure clear benefits at farm level, in terms of improved productivity and environmental sustainability, and profit. Training in Precision Farming technologies for farmers is essential. Farmers themselves must drive the demonstration of appropriate technology, to ensure a widespread adoption of Precision Farming.

2. Farm advisers should play a critical role in informing farmers on Precision Farming methods. This requires the development of specific data analysis tools with special emphasis on cost-benefits. Farm advisers will need to connect all members of the collaborative knowledge exchange initiative.

3. At present, the potential economic benefits of Precision Farming are not easily measurable. Stakeholders often lack the tools to calculate potential profits and benefits. This is partly due to unclear business models of Precision Farming methods and associated costs and benefits. Reliable Precision Farming calculator tools need to be developed that can take into account geographic regions and socio-economic variability across Europe. In addition, validated Precision Farming decision-support models and analytical tools need to be available for farm advisers and farmers.

4. Precision farming can also be useful for small and medium-sized farms, provided that ways are found to reduce investment needs and risk. Regional training and awareness can help in reaching advisers and small and medium-sized farms. Sharing and/or service contracting could be an efficient way to reduce risk and investment needs for precision farming in small and medium-sized farms (specialty high-value crop and livestock products).

5. Much progress has been made in terms of technical solutions, but major steps are still required for the introduction and further development of i) electric drives to facilitate precise electronic control of equipment and implements; ii) Internet of Things to facilitate machine and processor communication; iii) nanotechnology and biosensors; iv) drones and autonomous platforms. Multidisciplinary approaches in R&D, co-creation, on-farm research and process efficiency are critical factors.

6. Challenges for the successful adoption of shared data schemes exist, as farmers are generally reluctant to provide free access to their farm management data, including spatial data such as within-field soil variability, crop status and livestock data sets. Furthermore, compatibility issues in Precision Farming are limiting the development of technology, as it prevents data exchange between instruments, and interconnection of equipment. There is a lack of, or poor compliance with, standards for software development and data formats, limited data infrastructures on farms that are not designed for data sharing, and extensive brand protection by large companies.

7. More applied research, involving farmers, advisers and supply chain partners, is needed, instead of the traditional focus on laboratory activities or on research projects without any real potential applications. Relevant research should adopt a systems approach covering social, economic, environmental and technical aspects.

Further **recommendations** on what needs to be done to mainstream Precision Farming in Europe are described below:

1. The innovation process in Precision Farming should concentrate on developing farm management solutions that are focused on actual and practical farming problems and challenges for the majority of farmers. Solutions should be based on combinations of easy-to-use tools tailored to farm-specific

funded by European Commission

situations. Several decision support systems and farm management information systems have been developed, or are being developed. These would require testing in different real farm situations.

2. To tackle the complexity of mainstreaming Precision Farming, a collaborative effort involving several EU countries would be useful, for instance a multi-actor project on Precision Farming extension and technology transfer, looking at barriers, good practices, farmer-led initiatives and participatory approaches involving ambassador farmers, high-value Precision farming solutions for farmers and realistic business potential for suppliers, feedback from farmers. This would involve researchers, advisers, technology providers, and should have a clear focus on farmers' needs.

3. Advisers need appropriate analytical support tools and focused training packages to properly advise farmers on Precision Farming.

4. Validated Precision Farming decision support models and analysis tools, such as precision farming calculators which can help assess which Precision farming tools would be worth taking up on specific farms, are needed for farm advisers and farmer trainings.

5. We need Precision Farming tools that are designed for small and medium-sized farms; these should be easy to use, affordable and robust. Real case studies are essential to validate the case for PF techniques on these farms. Customised advisory services need to be developed, to meet the needs of small and medium-sized farms. Operational Groups in different sectors should be linked, and inter-regional exchanges should be encouraged.

6. Technical solutions need to be developed to generate 'as-applied' maps that can be combined with other data for making further management decisions. Farmers and cooperatives need to play a major role in innovation and in research of technical solutions. Overall technical solutions need to become smarter and integrated into farm management systems, to support farmers in their decision-making. The added value of these solutions should be tested, validated and demonstrated in practice.

7. New business models for data management are needed; sharing and open-data sources should be developed to bring Precision Farming to the next level. The recognition of data ownership is crucial. Portals that can facilitate the exchange of data form a prerequisite.

8. The creation of 'Precision Farming living labs' and development of networks of all stakeholders in the farming communities are required. The latter should involve farmers, advisors, technology providers and suppliers, in order to produce new research and innovative ideas.

The Focus Group suggested the following ideas for **Operational Groups**:

A: Operational Groups related to **technology and knowledge exchange involving farmers** could concentrate on the following ideas:

- The co-creation of Precision Farming data analysis and management tools such as web support/DSS systems.
- The co-creation of appropriate Precision Farming implementation/support packages for different regions, cropping systems, livestock systems, scale of farms, and suitability for socio-economic regions
- Testing decision support tools in different real farm situations. This will help identify barriers to adoption of these tools, and hopefully improve their usefulness.
- Clear cost-benefit (real business case) research to demonstrate the benefit of Precision Farming adoption in different scale/region/enterprise scenarios – allowing farmers to evaluate whether or not a certain technology could be worthwhile to adopt on their farm
- The development of appropriate technical support for independent (public or private) advisory services to ensure that precision farming methods are delivered as part of an integrated farm management package.

- An Operational Group created around issues related to prescription and 'as-applied' maps is required, to boost the use of technical solutions in Precision Farming, including the design and development of low-cost micro-sensors for sensor networks and data-collection by both terrestrial and moving platforms in the context of Precision Farming
- Operational groups are needed on remote sensing applications for agriculture, with a focus on nutrient management, disease detection, yield prediction, water stress detection and precision irrigation using combined imagery from unmanned vehicles (drones), manned aircraft and satellites. Regarding the use of drones, Operational Groups on the potential applications of drones and unmanned systems in the context of Precision Farming are needed in order to clarify the legal implications and the benefits of unmanned vehicles in agriculture. Work is needed regarding payloads and technical characteristics of drones under the current heterogeneous regulations within the EU.

B: Operational groups dealing with **investment risks and standardisation** could focus on:

- Cost-benefit analysis of Precision Farming components and complete Precision Farming systems, including risk mitigation, across all enterprises.
- Developing robust methodologies for automatic decision and planning support systems, and model-based process control in Precision Arable and Livestock Farming.
- Better quantify the actual benefits of different types of precision agriculture, including direct costs, indirect costs including work time, and physical and cognitive ergonomics (labour effects). The models used to determine the benefits should also include environmental benefits.
- Develop economic calculators for different cropping systems, geographical areas and socio-economic conditions within the EU.
- Operational Groups are suggested on topics such as data management and sharing, and for the development of common standards for data files, in the context of Precision Farming and Precision Livestock Farming.

C: Operational groups addressing the **needs of small and medium farm enterprises** could focus on:

- Developing Precision Farming best practices for small farm holdings/livestock, for instance focusing on specific crops, and livestock systems.
- Developing and testing sustainable infrastructures for sharing machinery, software, hardware and advisory services among small and medium-sized farming operations.
- Adding value by using Precision Farming on short-chain produce in specialised products
- Developing simple, cheap and 'plug and play' devices; these will allow farmers to test the benefits and the interest of Precision Farming / Precision Livestock Farming in a simple and immediate way, without major investments.
- Developing methods that require a small initial investment that can be directly applicable, minimising risk and ensuring profitability or contracting Precision Farming services.

funded by European Commission

Bibliography and References

Buning E. A. (2010). Electric drives in agricultural machinery - approach from the tractor side. 21st Annual Meeting Key Note Report, EIMA International, November 13-14, 2010, Bologna.

Delgado, JA, Kowalski, K., Tebbe, C. (2013). What DoNetflix and Drone Data Have In Common? The first Nitrogen Index app for mobile devices: Using portable technology for smart agricultural management, Computers And Electronics In Agriculture, Vol.91, pp.121-123

Didelot, D., Dörfler R, Fealy R, Holpp, M.; Kelly R., Latsch, A. and Thysen I. ICT-AGRI Strategic Research Agenda 42 p.

EIP-AGRI Service Point (2013). Focus Group "Reducing antibiotic use in pig farming", Final Report, 40 pp.

Ham J. (2014). Using 3D-printers and Low-cost Microcontroller Boards to Build Open-source Environmental Instrumentation. 31st Conference on Agricultural and Forest Meteorology May 12-15, 2014, Portland.

Hegedűs, B., Drexler, D., Gyuricza, Cs., Sárdi, K., Jung, A., Vohland, M. (2014). Rapid Monitoring of Organic Foliar Fertilizer Treatments on Organic Spelt by a Portable SPAD Meter and Field Spectroscopy. 34. Wissenschaftlich-Technische Jahrestagung der DGPF, 26. – 28. März 2014 in Hamburg, Gemeinsame Tagung der DGfK, der DGPF, der GfGI und des GiN (ISSN 0942-2870) 23/2014: 1-9.

Hegedűs, B., Garrett, E., Drexler, D., Jung, A., Gyuricza, C., Sárdi, K., (2013). Effects of Foliar Fertilizers on Grain Quality by Using SPAD Chlorophyll Meter. The 4th Scientific Conference on Organic Agriculture in Central and Eastern Europe, International Conference on Organic Agriculture Sciences (ICOAS), 9-13. October 2013, Eger, Hungary.

Huhtala, A., Suhonen, K., Mäkelä P., Hakojärvi, M., Ahokas J. (2007). Evaluation of Instrumentation for Cow Positioning and Tracking Indoors. Biosystems Engineering, 96(3), 399–405.

Jiang J.-A. (2014). Becoming technologically advanced - IOT applications in smart agriculture. 38th meeting of the Asia Pacific Advanced Network, August 11-15, 2014, Nantou.

Jung, A., Hegedűs, B., Vohland, M., Drexler, D. (2014): Rapid treatment monitoring by field spectroscopy. In: Proceedings of the 18th IFOAM World Congress, Istanbul, Turkey.

Jung, A., Vohland, M., (2013). High Resolution Remote Sensing for Organic Farming. The 4th Scientific Conference on Organic Agriculture in Central and Eastern Europe, International Conference on Organic Agriculture Sciences (ICOAS), 9-13. October 2013, Eger, Hungary.

Kempenaar C. (2014). Overview of topics and questions to be addressed by the FG Mainstreaming Precision Farming. Starting Paper for Focus Group meeting, June 3-4, 2014, Schiphol. http://ec.europa.eu/eip/agriculture/sites/agri-eip/files/fg_precision_farming_starting_paper.pdf

Kwong K. H., Wu T. T., Goh H. G. (2009). Wireless sensor networks in agriculture: cattle monitoring for farming industries, Proc. Progress In Electromagnetics Research Symp., March 2009, Beijing, China.

Meyer T. (2013). Farmers starting to capitalize on Big Data technology. October 08, 2013, L'Atelier, Paris.

Mertens K. C., Vangeyte J.; Van Weyenberg S., Van Haselberg C., Holpp M., Doerfler R., Thysen I. (2012). Web Based Research Mapping and Analysis: ICT-AGRI's Meta Knowledge Base Centralizes ICT and Robotics Development in Agriculture and Related Environmental Issues. Journal of Systemics, Cybernetics and Informatics, 10 (6), 2012, p. 36-39.

funded by European Commission

Mortari A. and Lorenzelli L (2014). Recent sensing technologies for pathogen detection in milk: A review Biosensors and Bioelectronics 60: 8–21

Nacke E. (2014). High Tech AG Machinery solutions – contradiction or contribution to sustainable agriculture? International Conference of Agricultural Engineering. July 6-10, Zürich.

Ogata K., (2010). Modern Control Engineering. Fifth Edition. Prentice Hall, New Jersey. 894p

Rai M. and Ingle A. (2012). Role of nanotechnology in agriculture with special reference to management of insect pests. Applied Microbiology and Biotechnology, 94(2):287-93.

Rao G. (2009) Optical Sensor Systems in Biotechnology. Advances in Biochemical Engineering / Biotechnology (116). Springer Heidelberg Dordrecht London New York

Rauch N. (2010). Experiences and visions of an implement manufacturer. 21st Annual Meeting Key Note Report, EIMA International, November 13-14, 2010, Bologna.

Russell, R. A. & Bewley J. M. (2013). Characterization of Kentucky dairy producer decision-making behavior. Journal of Dairy Science. 96 :4751–4758

Sanbo L. (2012). Application of the Internet of Things Technology in Precision Farming Irrigation System, International Conference on Computer Science and Service System. August 11-13, 2012, Nanjing.

Steeneveld W. & Hogeveen, H. (2015). Characterization of Dutch dairy farms using sensor systems for cow management. Journal of Dairy Science. 98:1-9.

Van der Flught P. (2014). Farm Equipment as component in the Future Internet, Smart AgriMatics, June 18-19, 2014, Paris.

Wolfert J. (2013). FIspace use case presentation. Fokus FUSECO forum, November 28, 2013, Berlin.

Zarco-Tejada, P.J., Hubbard, N., Loudjani, P. (2014), Precision Agriculture: An Opportunity for EU farmers – Potential support with the CAP2014-2020, Report for the European Parliament, Joint Research Centre (JRC) of the European Commission, Monitoring Agriculture ResourceS (MARS).

funded by European Commission

Annexes

Annex A. List of members of the Focus Group

NAME	FIRST NAME	NATIONALITY	ROLE
Bahr	Claudia	Germany	Scientist
Forristal	Dermot	Ireland	Applied researcher
Fountas	Spyros	Greece	Scientist
Gil	Emilio	Spain	Scientist
Grenier	Gilbert	France	Scientist and also farm adviser
Hoerfarter	Rita	Denmark	Advisory services, also farmer
Jonsson	Anders	Sweden	Farm adviser
Jung	András	Hungary	Scientist
Kempenaar	Corné	Netherlands	Coordinating Expert first meeting
Lokhorst	Kees	Netherlands	Scientist
Mazur	Piotr	Poland	Farm adviser
Mertens	Kristof	Belgium	From industry of manufacturing
Mottram	Toby	United Kingdom	Scientist, also farmer
Nacke	Eberhard	Germany	From industry or manufacturing
Paree	Peter	Netherlands	From agriculture organisation
Pastell	Matti	Finland	Scientist
Pickel	Peter	Germany	From industry or manufacturing
Šileikytė	Eglė	Lithuania	Advisory services
van den Borne	Jacob	Netherlands	Farmer
Vangeyte	Jürgen	Belgium	Scientist
Zarco-Tejada	Pablo J.	Spain	Coordinating Expert second meeting

You can contact Focus Group members through the online EIP-AGRI Network.
Only registered users can access this area. If you already have an account, you can log in here
If you want to become part of the EIP-AGRI Network, please register to the website through this link

funded by European Commission

Annex B. List of relevant research projects

TITLE	TOPIC	NAME	DESCRIPTION	START /END	FUNDING	COORDINATOR	WEBPAGE	Contribution by FG Expert
EU-PLF	Cost benefit	Bright Farm by Precision Livestock Farming	Precision Livestock Farming (PLF) could assist livestock producers through automated, continuous monitoring of their animals. The observation data can be translated into key indicators on animal welfare, animal health, productivity and environmental impact. A number of PLF tools have been developed at laboratory levels and as prototypes. The overall objective of the EU-PLF project is to bring some of those tools from the lab to the farm. The process of making those tools operational for the end user in dairy, pig and poultry farms will be studied in detail and a generic procedure (Blueprint) will be derived that will help people to develop Precision Livestock Farming concepts into operational tools in the future. This blueprint offers a manual for farmers and for high-tech SMEs that are keen to develop new PLF tools. It will be a reference tool offering pragmatic guidance on how Precision Livestock Farming (PLF) systems can be applied at farm level, to create value for farmers and other stakeholders.	11/2012 - 11/2016	FP7 project	Daniel Berckmans Daniel.Berckmans@biw.kuleuven.be	http://www.eu-plf.eu/	Claudia Bahr and Kees Lokhorst
Smart Dairy Farming	Research needs to boost innovation and knowledge transfer in Precision Farming	Smart Dairy Farming	The Dutch Smart Dairy Farming (SDF) consortium works on proof for the concept and on the development of sensors, IT infrastructure, decision models and working instructions designed to support dairy farmers and farm advisers in extending the lifespan of their cows. Various companies (chain partners Friesland Campina, CRV and Agrifirm), IT companies and SMEs), knowledge institutions (WUR, TNO, UU)	SDF 1.0 2011-2014 SDF 2.0 2015-2017	National funding (SNN, Ministry, Dutch Dairy Board, Mesdag, LTO, company contributions)	Bart Jan Wulfse bjwulfse@smartdairyfarming.nl	http://www.smartdairyfarming.nl/	Kees Lokhorst

	Data management and compatibility		and dairy farmers are working together on the development of these innovative tools in the area of animal health, fertility and nutrition. This way they contribute to making the dairy chain more sustainable. To successfully develop these tools, a platform is required to make real-time sensor data, from different farms, available to model developers. The data must be made available via a standard interface on an open platform in real-time at the individual animal level. The concept of an InfoBroker is designed as a breakthrough when it comes to making data that are stored in diverse places available in an efficient manner. The InfoBroker is capable of retrieving individual cow data from an infinite number of sources, while at the same time serving a large number of models on demand. The InfoBroker can specify which data may be released for each farm. This means that the farmer always stays in control.					
HighResOrganic	Research needs	High Resolution Remote Sensing for Organic Farming	Applied remote sensing methods known in conventional agriculture can be used in organic farming as well. Remote sensing techniques are often called 'chemical imaging'. This technique enables non-destructive chemical analyses without chemicals and can estimate vegetation and soil parameters (moisture content, biophysical indices, phenology, biotic and abiotic stress, phytopathology etc.). The sensor (spectral camera, field spectrometer) can be hand-held, vehicle-based, air-borne (multicopter) or even space-borne (satellites). Spatial, temporal and chemical (spectral) resolutions differ from platform to platform. Our project intends to identify those remote sensing solutions and methods that could be integrated successfully into organic farming. The very first project analyses the relationship between spelt protein content and four different leaf fertilisers, by means of spectral footprints used in field spectroscopy and predictive models.	04/2013-04/2016	Granted by ÖMKI, Hungary	András Jung andras.jung @biokutatas.hu	http://www.biokutatas.hu/kutatasok/taverzekeles (in Hungarian)	András Jung

funded by European Commission

Sustainable Precision Feeding of Fattening Pigs	Technical solutions, Cost benefit		The project aims to develop a Precision feeding system for fattening pigs, in which the optimal feed mixture for each individual pig in a group is continuously optimised using sensors and an adaptive mathematical model, resulting in an optimised use of feed, reduced nutrient excretions and improved profit for the farmer. 2 pig farms are involved.	12/2013-12/2015	National or Regional Research and Innovation sources	Agrifirm Belgium, Adrie Brands	-	Claudia Bahr
PIGWISE: Optimising performance and welfare of fattening pigs using High Frequent Radio Frequency Identification (HF RFID) and synergistic control at an individual level	Technical solutions/ Data Management and Compatibility		An IT-based tool is developed to monitor performance, growth and welfare of pigs at an individual level. This tool allows detecting problems in an early stage (monitoring and decision support) and hence preventing economic losses. Individual feeding behaviour of group-housed pigs is monitored by means of HFRFID, enhancing the conventional feeders for fattening pigs by HF RFID equipment (sensors and readers). To avoid errors caused by simultaneous registration of several animals staying in the area within "reading range" of the antenna at the same time, the state-of-the-art anti-collision system is used. HF transponders are attached to the ear tags of the pigs, while the camera vision-based identification system is a layer upon the RFID identification system used for validation of the HF RFID technology. A broad approach will be undertaken, combining an innovative individual online monitoring system based on RFID with HF transponders, camera vision technology and software. Accurate advanced computer-aided analysis of data from individual animals enables treating each animal as a production unit (instead of the pen or the herd), defining animal-based threshold values and hence developing early warning systems for potential drops in performance or potential health and consequently performance and welfare problems. For example, a pig displaying a reduced number and duration of feed visits, or even a lack of visits or too long pauses between	11/2011 - 11/2015	FP7 combined with IWT funding, the government agency for Innovation by Science and Technology	Engel F. Hessel earkena@gwdg.de	**www.pigwise.eu** **https://www.youtube.com/watch?v=VLe39tf164k**	Jürgen Vangeyte

funded by European Commission

			visits, will be timely signalled and the pig farmer can intervene quickly. Also, a sudden change in activity rate may be caused by an arising lameness problem or problems with agonistic behaviours like tail biting, alerting the farmer to intervene and separate the animals that need special attention. This would mean that negative influences on animal health or economic losses can be prevented.					
NYT - Modern barn technology	Technical solutions	Modern barn technology	Increased scientific knowledge about the reliability and practicality of several new measurement systems for dairy producers and researchers. Of technologies and methods measuring and observing production, health and welfare of dairy cows. These include lying time measurement, eating, drinking and rumination monitors, heart rate, milk progesterone and rumen pH. Increasing herd size often leads to more automated production, and thus technological choices are one of the challenges in modern milk production. The Modern Cow Barn Technology project (NYT) tested new and developing barn technologies in MTT Maaninka's CowLabTM research barn.	1/2010 - 6/2014	ESR/EAKR	Jaakko Mononen jaakko.mononen@luke.fi	**http://www.mtt.fi/mttraportti/pdf/mttraportti141.pdf**	Matti Pastell
PPP Precision Agriculture 2.0	Technical solutions/ Data Management and Compatibility	PPP Precision Agriculture 2.0	Combines various topics: satellite observations, ground sensors, site-specific tillage, crop care and harvest techniques, yield maps, controlled traffic farming (CTF), robotics, Early Warning Systems (EWS), Decision Support Systems (DSS), Information and Communication Technology (ICT), tracking and tracing within food and feed chains, wireless networks and Farm Management Systems (FMS). At its core PA consists of four steps: (1) **detection** of heterogeneity in crop, soil, climate and pests (2) **decision** how to respond to this information, (3) site-specific **implementation** and (4) **evaluation.** Reduce the use of resources (water, fertilisers, agro-chemicals, energy) in agriculture, to increase crop yields and quality, and to let the	1/2015 - 12/2017	National or Regional Research and Innovation sources	Geert Hermans geert.hermans@zlto.nl	**http://www.precisielandbouw.eu/home/english**	Peter Paree

			environmental impacts of agriculture decline. Vision technology for detecting diseases in potato crops; soil sensor technology, variable rate technology; reports on the R&D to integration of sensors, models, metrics and use databases in consultancy; Management of grass, maize and crops; plot characteristics yield potential; strategic land planning. Knowledge exchange with coordinators of CoE and CIV.					
eCow Data Service System	Integrating data about dairy cows from multiple sources (rumen pH, milk yield, robotic milking visits	eCow Data Service System	Building an infrastructure to allow data from multiple third party sources to be integrated and analysed by third parties.	2014-2015	TSB	Toby Mottram	**Www.ecow.co.uk**	Toby Mottram
Agricultural Informatics and Metrics of Sustainability	Agricultural Informatics and Metrics of Sustainability	AIMS	Creation of a new informatics centre dedicated to agricultural information and the metrics of sustainability	2015-2025	Agritechnology Governing Council for Precision Farming	Prof. John Crawford john.crawford@rothamstead.ac.uk	**Www.rothamstead.ac.uk**	John Crawford
BioSoM		Biological Soil Mapping	Aims to provide scientific support to new services for farmers, enabling detection and mapping of soilborne pathogens. The research results are intended to constitute the foundation for commercial product launches by some BioSoM stakeholders and to be used by others to serve farmers. The programme was initiated after farmers who had problems with club-root contacted an adviser, who contacted a commercial agricultural laboratory asking about the possibility to determine the presence of pf *Plasmodiophora brassica* (causing club-root) in soil. After contacts with research at the agricultural university a	2009-2015	50 % faculty and 25% from R&D-foundation and 25% “in kind” Stakeholder Companies	Anders Jonsson anders.jonsson@slu.se	http://www.slu.se/en/departments/soil-environment/research/precision-agriculture-and-pedometrics/biological-soil-mapping-biosom1/publications/	Anders Jonsson

funded by European Commission

			thematic programme was launched and work initated with methods for the detection of pathogens such as Aphanomuces euteiches, *A. cochlioides* and *Verticillium* spp. A mapping service is now available.					
SILF: Smart Integrated Livestock Farming: integrating user-centric & ICT-based decision support platforms	Technical solutions/ Data Management and Compatibility/ The Cost-Benefit of Precision Farming	Smart Integrated Livestock Farming: integrating user-centric & ICT-based decision support platforms	SILF will demonstrate the possibilities, explore the boundaries and requirements, and identify future developments for ICT-supported Smart Farming systems for dairy production. SILF will use the example case animal welfare (lameness) and resource consumption (energy) to demonstrate how sensor technology combined with databases and suitable models can lead to sustainable livestock production. The sensing systems along with production data (e.g. national milk records from Denmark and Ireland and demonstration farms in the participating countries) will be integrated through pre-defined operating scenarios at animal and farm level to create economic, welfare and environmental added-value, while also identifying specific business models for the farmer and the production-supply chain as a whole. In this project we will develop an evaluation platform that demonstrates, through research, the potential for an Internet of Things (IoT) enabled FMIS with animal-centric ICT, production databases & best practice standards to assist farmers in optimising sustainable livestock production. In this respect SILF will take an integrated approach to solving issues with environmental impact and animal welfare during livestock production. Previously developed Smart Farming sensing systems for lameness detection in dairy production will be robustified, validated and evaluated against other available systems in different member states. The commercial/environmental benefit of these systems along with 'object-connected ICT' will be realised through specific business models and	3/2013 – 2/2016	Other EU Research and Innovation sources ICT-AGRI	Grøn Sørensen claus.soerensen@eng.au.dk	-	Matti Pastell/Jürgen Vangeyte

funded by European Commission

			lifecycle costing for farming systems. To entice innovation adoption, these benefits will be disseminated through different means, e.g. through the use of a virtual farm simulator.					
Targeting Precision	An integrated research and demonstration project	Targeting a Precision Agriculture approach to crop monitoring and management via the BETTER farm programme on tillage farms	Targeting Precision is an integration research, demonstration and technology transfer project funded by Teagasc core research fund. The key objectives of the project are: To determine and demonstrate within- and between-field crop variability on a limited number of farms (3 to 6 BETTER farms) and to develop a simple targeted investigative approach to determine the factors influencing that variability. To determine and demonstrate crop management responses to spatial yield variation that allow production from these areas to be optimised. To demonstrate and assess the role of a number of technologies (satellite sensing, proximal reflectance crop sensing and smart-phone leaf area assessment) in determining yield potential and offering scope to determine optimum management strategies during the growing season. To demonstrate and disseminate the concepts of Precision Agriculture; the field, positioning and analysis technologies associated with it; and its potential now and in the future to facilitate spatially variable management practices to optimise production.	1/7/2014 – 1/7/2017	Research & Technology transfer programme	Dermot Forristal Dermot.forristal@teagasc.ie	-	Dermot Forristal
Meeting the challenges of the farm of tomorrow by integrating Farm Management	Farm Management Information System	FUTUREFARM	The aim of the project was to tackle the current situation where, although most people can see the benefits of using a more precise approach to manage crops with additional information, the tools provided by Precision Farming and other information technologies have not yet moved into mainstream agricultural management. The	2008-2011	FP7 project	Simon Blackmore simon.blackmore@harper-adams.ac.uk	**http://www.futurefarm.eu**	Spyros Fountas

Information Systems to support real-time management decisions and compliance to standards			increased complexity of the systems inhibits easy adoption and makes calculations as to the financial benefits uncertain. These issues were studied and tried to be resolved by improving the decision making process though better Management Information Systems, improved data interchange standards and clear management methods.					
Integrated robotic and software platform as a support system for farm level business decisions	Agricultural robotics – Farm management information system	ROBOFARM	ROBOFARM aims to create a technology platform that integrates and harmonises existing software and hardware technologies into a single system and makes use of robots equipped with sensors and active vision systems to automatically collect data from the field, feeding a farm management DSS and considering the agronomical, environmental and food safety aspects.	2011-2013	ERA-NET ICT-AGRI	Maurizio Canavari *maurizio.canavari*@unibo.it	**http://robofarm.unibo.it/**	Spyros Fountas
Usability of environmentally sound and reliable techniques in Precision Agriculture	Precision Agriculture in orchards and vineyards	USER-PA	The aim of the USER-PA project is to develop and demonstrate an integrated and reliable Precision Agriculture solution for orchards and vineyards considering spatial information on irrigation and harvest management. USER-PA proposes a conceptual framework, an innovative technical architecture, and the enabling technologies that will allow integrating canopy and fruit sensors with mobile and static data acquisition systems, and farm management information systems, targeting a system that will serve farmers.	2013-2016	ERA-NET ICT-AGRI	Victor Alchanati victor@volcani.agri.gov.il	**https://asaf1a1.wordpress.com/news/**	Spyros Fountas
INNO+	Future Cropping	1) IT-platform 2) Variable N application 2a) New N algorithms	INNO + is a new big project on Precision Farming. Focus on an IT-platform to solve file format problems, fertiliser, environment **Fertiliser:** 1) Develop at new variable N application algorithm 2) Prove that variable N application results in less N leaching to the environment	2015-2020	EU project Innovationsfonden, Research, technology growth in Denmark Farmers, local advisers,	Katrine Hauge Madsen, SEGES, khm@seges.dk	-	Rita Hørfarter

		2b) prove the Variable N application gives less leaching	3) Hope that this will allow Danish farmers to apply more nitrogen to the crops when spreading N variable instead of uniform 4) Test new methods to define the phosphorus status in the crop		SEGES, research, private companies			
Farm Intelligence solutions for Livestock Production (SME Innovation Project partly funded by IWT Flanders)	Precision Livestock Farming	Big Data concepts and analytics for improved management	(1) Build a big data platform (back-end) focused on livestock production (2) "Farm Intelligence" for poultry production based on advanced statistical analysis. Transform technical KPI information into actionable management information. (3) Build a user application with a simple/attractive/intuitive dashboard.	Porphyrio NV	R&D Phase	kristof.mertens@porphyrio.com	**www.porphyrio.com**	Kristof Mertens
GPS-EGNOS based Precision Agriculture using Unmanned Aerial Vehicles	Technical solutions	Fieldcopter	Unmanned Aerial Systems (UAS) are an up-and-coming method in providing farmers with (near-) real time sensing information for Precision Agriculture applications such as water stress monitoring, detection of nutrient deficiencies and crop diseases. The EU funded project FieldCopter provides state-of-the-art multi-spectral cameras on UAS that deliver the right information in the right time on the right spot, developing a complete solution for UAS sensing.	2012-2014	Market phase	pablo.zarco@csic.es	**http://fieldcopter.eu/**	Pablo J. Zarco-Tejada

Annex C. List of relevant working groups

Type of action	Topic	Thematic area concerned	Goals	Actors involved	Scale/level of implementation	Details	Relevance	Contribution by FG Expert
Cow Sensor: "Individual follow-up of fertility in dairy cattle, on the basis of on-line milk measurable parameters"	Empowerment of farmers and advisers/technical solutions	Technology knowledge dissemination in dairy	More, better and more efficient use of commercially available sensors Development of new innovative sensor technology for dairy farming Cooperation between research and farmers for better fertility results of the Flemish dairy.	Farmers, Technology providers, Research institutes	National	**www.koesensor.be**	Introduce new tools and techniques to improve fertility results of the high-productive dairy cattle and to ensure the economic sustainability of dairy farming. Get it introduced into practice.	Jürgen Vangeyte
Spectral Field Sensing for Organic and Sustainable Agriculture	Research needs for innovation and knowledge transfer	Testing rapid sensing techniques and developing low-budget RPAS solutions	1) This project analyses the relationship between spelt protein content and four different leaf fertilisers by means of spectral footprints used in field spectroscopy and predictive models. 2) RPAS-based spectral sensing for wheat nutrition supply and yield quality.	University of Leipzig (Germany), Research Institute of Organic Agriculture (Hungary), ELTE (Hungary), Farmers	First experiments, results and publications: http://www.andrasjung.de/research/industry-projects/	**http://www.biokutatas.hu/kutatasok/taverzekeles**	Introduction of spectral sensing techniques in organic farming in Hungary. Overcome technical deficits.	András Jung
VarkensNET	Networking for innovation	Knowledge sharing in the pig sector	Network for pig producers in Holland – share problems to initiate new R&D projects with universities	Pig Producers VIC Sterksel (WUR) LTO	Running	**http://varkensnet.nl/**	Farmers go to (practical) researchers with their problem, researchers launch a project for subsidies and for engaging private partners.	Kristof Mertens and Kees Lokhosrt

funded by European Commission

Precision Farming Sweden (POS)	R&D platform	New techniques in crop production	The general aim has been to test the up-coming PA-technics for crop management. Including yield mapping, variable rate application of lime and PK; forage management and on-line quality; sensors for NDVI (Crop scan , YARA N-sensor) and satellite images.	AgroVäst AB Companies ex. YARA Farmers Union, The Agricultural University (SLU), Regional authorities	The results have been presented at local activities for farmers and at national exhibitions since 20 years.	**http://www.agrovast.se/precision/**	Farmers are directly involved in the steering committee of the POS programme and are active in some of the projects	Anders Jonsson
Koeien en Kansen	Empowerment of farmers and advisers	research needs to boost innovation and knowledge transfer	Many dairy farmers believe that not only technique and the economy are important to business development, but also the voice of society gets an increasingly important role. In this project, a group of 16 enthusiastic dairy farmers explores, together with researchers, the potential of a sustainable and socially accepted dairy farming.	Farmers and researchers	A group of farmers forms the core. On their farms, research and innovation is done to experience and show that the concept of circular farming is possible and that you can show as a farmer that you can do a good job. Results influenced product development and national legislation on N efficiency.	**http://www.koeienenkansen.nl/nl/koeienkansen-1.htm** On-farm research and demonstrations are combined with workshops and communication.	Farmers and researchers act as equal partners, each with their own expertise. Prototyping is applied into practice. This means that we set up an enterprise system in practice, based on existing knowledge and practical objectives. This process is then intensively followed-up, and adjusted depending on results.	Kees Lokhorst
Boeren en Klimaat	Climate effect of PA	Research on effects	16 Farmers, common and organic farms from arable farming, pig and poultry farming are monitoring their energy and CO2 efficiency with WUR research. Inventory in arable	Farmers and researchers	NL, samples	**http://www.boerenklimaat.nl/NL**	Reliable facts of effect of PA	Peter Paree

funded by European Commission

			farming shows e.g. that only CTF reduces 10% on diesel and inputs.					
H-WodKa	Use PA for optimal interaction between societal claims on soil	agriculture, nature, recreation	All partners work together in an area in the Netherlands. H-Wodka has an advisory role in the implementation of the projects. H-Wodka bases its plans especially on the use of GPS and GIS technology. It considers that developments on the basis of these new technologies are important for improving the vitality of agriculture as an effective and efficient management of the landscape.	Farmers' initiative together with NGOs and government	Suburban region South of Rotterdam	http://www.hwodka.nl/	It seeks specifically to cooperate with parties that have shared interests in the outdoor area, and for knowledge and experience in the field of GPS and GIS	Peter Paree
IPM – Plant protection	Empowerment of farmers and advisers	In this project each farmer defines his own way to practice IPM. Two of the farmers focus on Precision Farming	7 demonstration farms have been established in Denmark - 5 in agriculture and 2 in horticulture. On each farm, the farmer will be advised on the general IPM principles. The farmers then decide which of the IPM principles is relevant for or of interest to them. Two of the farmers have implemented Precision Farming And one says - "The last few years, sensor control has provided many technical challenges, but it's going well now. We use sensor control fungal sprays, and here we have gone down in dosage"	Farmers, local advisers, advisers from SEGES, researchers	-	The project: https://www.landbrugsinfo.dk/planteavl/plantevaern/ipm/sider/startside.aspx The farmer: https://www.landbrugsinfo.dk/Planteavl/Plantevaern/IPM/demobrug/Sider/PeterMichaelsen-Hjallerup.aspx	The farmer defines, by himself or together with the local adviser, what is of interest for him in the IMP principles. In the project there have been more open field days.	Rita Hørfarter

Annex D. List of documented best practices

Title	Topic	Description and results	Actors involved	Funding source	Website	Contribution by FG Expert
The YARA N-Sensor and Satellite-N	Technical solution	Variable-rate N-application in wheat, malting barley and oilseed rape. Approx. 110 N-sensor is running in Sweden covering approx. 10-15% of the Swedish winter wheat crop. In 2014 a new service based on satellite-images (i.e. NDVI) was developed and test-launched to farmers by the POS-platform. A calculation of variable-rate N-application based on the NDVI-satellite map on any field in southern Sweden	Farmers, YARA, POS-programme	YARA Regional R&D source Swedish Farmers' Foundation for Agricultural Research (SLF)	The page for the N-service based on satellite-NDVI **http://vegetationsindex.datavaxt.se/**	Anders Jonsson
Milkcontrol	Technical solution / Data Management and Compatibility / Support for Advisers	A good milking machine installation, as well as the operation and maintenance thereof, are essential to warrant good udder health of the cows and to ensure milk of impeccable quality. The maintenance of the milking installations and cooling tanks is performed by specially trained staff, i.e. milking machine and cooling tank technicians.	Farmers and dealers , farmer cooperations, companies	Other sources	**www.milcontrol.be**	Jürgen Vangeyte
ISENSE	Empowerment of farmers / Technical solutions	To encourage the use of sensor technology. Biosensor-case: Need for high-performance and affordable sensors for rapid detection of chemical or biological targets in real life agri-food matrices. Precision Livestock Farming-case: Need for good and affordable sensor systems for monitoring of stable climate and ammonia emissions.	Farmers, breeders, machine developers, research institute	National or Regional Research and Innovation sources	**www.isense.eu**	Jürgen Vangeyte

funded by European Commission

		Precision Crop Farming-case: Geospatial variability is too little exploited in practice				
Precision Agriculture School	Cost-benefit	I.WEB-pages were you can calculate the cost and benefit from variable rate-application of N (using YARA N-Sensor) and P and K. The benefit and cost for liming is also included. All commercial soil-mapping products include a data file for VRA of lime.	POS and stakeholder companies	AgroVäst AB Swedish Farmers' Foundation for Agricultural Research (SLF)	http://www.precisionsskolan.se/	Anders Jonsson
iGreen	Open data	This project in Germany developed an open data architecture for communication of stakeholders and an infrastructure based on methods of the semantic web	Research organisations, public & private Consulting entities, farmers and contractors, Agricultural equipment producers, governmental organisations	German Ministry for Research and Education (BMBF)	http://igreen-projekt.de/iGreen/index.php?id=47	Peter Pickel, Eberhard Nacke
GEOPORTAL	Open data	Web platform in Poland with cadastral maps, browsable	National Infrastructure of Spatial Data (Krajowej Infrastruktury Informacji Przestrzennych - KIIP)	Sectorial Operational Programme Improvement of the Competitiveness of Enterprises 2004-2006 - Poland	http://www.geoportal.gov.pl	Piotr Mazur
InfrAgrar	Open data	KTBL farming data services (Germany)	KTBL (German ass. supporting technology transfer)	German Ministry for Nutrition and Agriculture (BMEL)	http://www.ktbl.de/	Peter Pickel
Topps	strategies for small and medium-sized farms	Training project for avoiding water contamination during pesticide application. Punctual and diffuse sources are the focus of this extension project. 16 EU members participate in the project. Best	Universities, Research Organisations, advisers, farmers	Life project (EU)	http://www.topps-life.org/	Emilio Gil

funded by European Commission

		Management Practices have been developed.				
MecaOlivar	strategies for small and medium-sized farms	R&D to improve technology and economic performance of the Spanish olive sector. Special interest on improvement of spray application technologies and harvest process.	SMEs, Industry, Universities, Research Organisations	Spanish Ministry of Economy and Competitiviness	**http://www.mecaolivar.com/**	Emilio Gil
GreenVineyard	Precision Viticulture	The project results were the development of an innovative approach that integrates Precision Agriculture (PA) technologies and Integrated Crop Management (ICM) practices in order to protect natural resources and sustain a profitable future for grape and wine production.	SMEs, Research organisations	Greek General Secretariat of Research and Development	**http://www.draxis.gr/en/projects/projects_gis**	Spyros Fountas
Fitovid	strategies for small and medium-sized farms	Demonstrations of strategies to reduce the negative environmental impacts from the production of grape, juice and wine	Universities, Research Organisations, advisers, farmers	Life project (EU)	**www.fitovid.eu**	Emilio Gil
Praktijknetwerken	research needs to boost innovation and knowledge transfer	A programme stimulated by the Dutch government has been applied where farmers could form a group on a specific topic. Experience and knowledge has been developed in setting up and coaching these groups. Specific tools can be used to inspire them, to work together, to receive impact.	Farmers, advisers, SMEs, knowledge institutions.	Dutch Ministry of Economic Affairs	**http://www.praktijknetwerkenindelandbouw.nl/**	Kees Lokhorst and Corne Kempenaar
Akkerweb	research needs to boost innovation and knowledge transfer	Internet environment where location-based information is visualised. The web environment was started in collaboration between WUR and Agrifirm, a farmers' cooperative. Research information can be published here in a user-friendly way.	WUR, Agrifirm, public finance	Dutch Ministry of Economic Affairs, SNN	www.Akkerweb.nl	Peter Paree and Corne Kempenaar

GeoWebAgri	research needs to boost innovation and knowledge transfer	to analyse and develop an ICT infrastructure for handling geospatial data and knowledge both in agricultural machines and farm management information systems (FMIS), and to promote the introduction of this technology in European software and automation products for agriculture.	Universität Hohenheim	ICT-Agri/Eranet BLE (local authority)	**www.uni-hohenheim.de/project/geowebagri-9**	Eberhard Nacke
EU-PLF	research needs to boost innovation and knowledge transfer	The overall objective of the EU-PLF project is to bring some of those tools from the lab to the farm. The process of making those tools operational for the end user in dairy, pig and poultry farms will be studied in details and a generic procedure (Blueprint) will be derived which will help people in the future to develop Precision Livestock Farming concepts into operational tools. This blueprint represents a manual for farmers and high tech SMEs that are keen to develop new PLF tools. It will be a reference tool offering pragmatic guidance on how Precision Livestock Farming (PLF) systems can be applied at farm level in order to create value for farmers and other stakeholders.	Researchers, farmers, Industry, SMEs	FP7	**http://www.eu-plf.eu/**	Claudia Bahr and Kees Lokhorst
Pig Cough Monitor	research needs to boost innovation and knowledge transfer, cost benefit	The system continuously monitors the number of coughs that occur in your pig compartment, 24h/24h, 7d/7d. Depending on specific needs, SoundTalks offers modified solutions for farmers, veterinarians and researchers. In an easy-to-use website system, farmers can consult all the desired information and monitor the health status of the pigs in an objective and	SMEs, researchers, Vets, farmers	National or Regional Research and Innovation sources	**http://www.soundtalks.be**	Claudia Bahr

		reliable way. Localisation of the cough sounds (individual tracking of animals during test trials), warning by SMS in case an infection occurs... are just some of the possible features of the system.				
Smart Agri-Food, FiSpace	Introduction of next generation ICT	Future internet for safe and healthy food from farm to fork, to boost the application and use of Future Internet ICTs in the agri-food sector by a user-centred methodology. The use case specification will be developed with a particular focus on transparency and inter-operability of data and knowledge across the food supply chain.	Big companies, universities	FP7	**http://smartagrifood.eu/**	Peter Paree and Corne Kempenaar
Ekotoxa	Empowerment of farmers	Practical training on GPS use for farmers. The training helps farmers to choose the techniques that fit their circumstances, and give the basic knowledge to use them.	Clients: local coalitions of farmers in CZ,PL etc.	Different projects, e.g. Unifarm (GSA)	**http://www.ekotoxa.cz/**	Peter Paree
Van den Borne Aardappelen	Empowerment of farmers	Developer of sensing methods connected to Precision applications, and translates all kinds of sensor information to machine tasks e.g. for variable application of N fertilisation. In this way, a proof of principle is tested in practice before expensive programming is started. In addition, colleagues recognise VandenBorne as a main-stream grower, because he explains his difficult work in everyday language and he explains the advantages, e.g. that Controlled Traffic Farming saves 10% of the overlap. He links the advantages together in the management cycle.	Farmer and researchers	Other and own resources	**http://www.firestarters.nl/nl/detail/documentary/firestarters-the-series-seizoen-2-01-old-macdonald-had-a-drone** **http://www.vandenborneaardappelen.com**	Jacob van den Borne

JDLINK, AGCOMMAND, EASY	Communication, Telematics	Agricultural machinery manufacturers sell Geo-based management and task support programmes: JDLINK, AGCOMMAND, EASY are brand-specific. Farmpilot, produced by Arvato ('best software as service in the public cloud') connects machines of more brands. It links farming machinery, end devices, and software. Farmers and contractors can exchange task and machine data between their farm computers and mobile devices in real time.	Agricultural equipment producers	n/a	http://www.farmpilot.de/de.html	Eberhard Nacke Peter Pickel
Rapid Monitoring of Organic Foliar Fertilizer Treatments on Organic Spelt by Portable Devices	Research needs	Effects of foliar fertilisers on grain quality were analysed in Organic Farming production. First results did not show significant improvements. The reason for this was the inappropriate number of samples and the low-resolution sensing strategy. The experiment has been continued, the spectral resolution of sensing devices and the number of samples have been significantly increased in the second phase of the project. Results are still under evaluation. The most important goal is to help finding effective foliar fertilisers (without doing intensive chemical analysis) for farmers engaged with Organic Farming.	ÖMKI, Hungary; Leipzig University, Germany;Szent István University, Hungary; University of Pannonia Georgikon, Hungary, Farmers	Granted by ÖMKI; Hungary	http://omki.org/andras-jung/	Andras Jung
Agvance	Research	Study of the use of photonic-based tools for a sustainable agronomic management and use of pesticides in tree crops in the framework of Precision Farming	Universities, researchers, industry	Spanish Ministry of Economy and Competitiveness	http://www.uma.deab.upc.edu	Emilio Gil

funded by European Commission

eip-agri

AGRICULTURE & INNOVATION

The European Innovation Partnership 'Agricultural Productivity and Sustainability' (EIP-AGRI) is one of five EIPs launched by the European Commission in a bid to promote rapid modernisation by stepping up innovation efforts.

The **EIP-AGRI** aims to catalyse the innovation process in the **agricultural and forestry sectors** by bringing **research and practice closer together** – in research and innovation projects as well as *through* the EIP-AGRI network.

EIPs aim to streamline, simplify and better coordinate existing instruments and initiatives and complement them with actions where necessary. Two specific funding sources are particularly important for the EIP-AGRI:

- ✓ the EU Research and Innovation framework, Horizon 2020,
- ✓ the EU Rural Development Policy.

An EIP AGRI Focus Group* is one of several different building blocks of the EIP-AGRI network, which is funded under the EU Rural Development policy. Working on a narrowly defined issue, Focus Groups temporarily bring together around 20 experts (such as farmers, advisers, researchers, up- and downstream businesses and NGOs) to map and develop solutions within their field.

The concrete objectives of a Focus Group are:

- ✓ to take stock of the state of art of practice and research in its field, listing problems and opportunities;
- ✓ to identify needs from practice and propose directions for further research;
- ✓ to propose priorities for innovative actions by suggesting potential projects for Operational Groups working under Rural Development or other project formats to test solutions and opportunities, including ways to disseminate the practical knowledge gathered.

Results are normally published in a report within 12-18 months of the launch of a given Focus Group.

Experts are selected based on an open call for interest. Each expert is appointed based on his or her personal knowledge and experience in the particular field and therefore does not represent an organisation or a Member State.

*More details on EIP-AGRI Focus Group aims and process are given in its charter on: **http://ec.europa.eu/agriculture/eip/focus-groups/charter_en.pdf**

funded by European Commission

www.eip-agri.eu | +32 2 543 73 48 | servicepoint@eip-agri.eu | Avenue de la Toison d'Or 72 | 1060 Brussels | Belgium