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ICT-AGRI 2016 Action Plan

for implementation of the Strategic Research Agenda

with focus on

Farm Management Systems

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1. Introduction

In the first ICT-AGRI ERA-NET, a strategic research agenda (SRA) has been developed in 2012. It describes the main challenges, goals and solution domains of the application of ICT and robotics in the agricultural sector. One of the objectives of the current ICT-AGRI-2 ERA-NET is to implement the SRA. This means that the SRA is translated into yearly action plans that describe specific actions to be taken in order to stimulate research and innovation in the topics identified by the SRA. This document is the second yearly action plan that describes actions to be taken by the ICT-AGRI-2 ERA-NET in 2016.

1.1. Background

The SRA concluded that Europe and the associated countries have a huge potential to produce high quality and safe food for a continuously growing market due to its leading role in the agricultural engineering sector. The food control along the value added chain is highly developed. On the other hand, the agriculture in Europe and the associated countries is under strong competition, because many other countries in the world are able to produce at lower costs. A cutback of subsidies on both the European and national levels is imminent. The legal and administrative requirements for an environmentally friendly land use and animal friendly livestock production systems increase. Meanwhile new future challenges such as climate change and protecting biodiversity are rising.

According to the European Commission for Agriculture and Rural Development agricultural income per (annual) worker in the EU-27 has grown over the last decade both in nominal and in real terms. On average, however, the increase in real terms has been very modest (0.6 % per year) and the development in recent years has shown, that agricultural income is highly volatile. To strengthen the international competitiveness of European farmers and to reduce the negative impact of agricultural production on the environment are key concerns of the ICT-AGRI ERA-NET. Furthermore, ICT-AGRI aims at facilitating the application of information and communication technologies and implies that farmers use these technologies to meet the challenges agriculture will be faced with in the decades to come.

In the SRA new perspectives in ICT applied in agriculture are proposed. It identifies future challenges for a sustainable European agriculture and deduces goals and solution approaches based on ICT and automation technologies. Further needs for research and innovation (R&I), are determined and prioritized. Finally also a vision for ICT and automation in agriculture together with a road map for SRA implementation is created.

1.2. Main outcome of the SRA

On the background of the future challenges ICT-AGRI has identified goals for a sustainable European agriculture, which are particularly depending on ICT and automation and solutions contributing to these goals (see Figure 1). Precision agriculture and precision livestock farming rely on the use of information and communication technologies including sensors, (global) positioning and decision support systems etc. The collected data enable the farmer to precisely dose fertilizers and pesticides or the application of seeds and other inputs via regulation of agricultural machines. ICT permits the optimized application of inputs and therefore reduce adverse impacts of agriculture on the environment. They can help to enhance the efficiency of food production and to obtain higher outputs, while inputs decrease.

Based on a review of current technologies used in plant and animal production the solutions were designed to cover nearly all contributions of ICT and automation to primary agricultural production and to agriculture related environment. The solution Farm Management and Information System (FMS) is defined as the backbone system for the other ICT and automation solutions prioritized by ICT-AGRI. The concept of solutions highlights the need of interdisciplinary collaboration and interoperabilty. It is not enough to invent a machine capable of variable rate application; it is also necessary, for example, to include the interaction with farm management or the economic consequences.

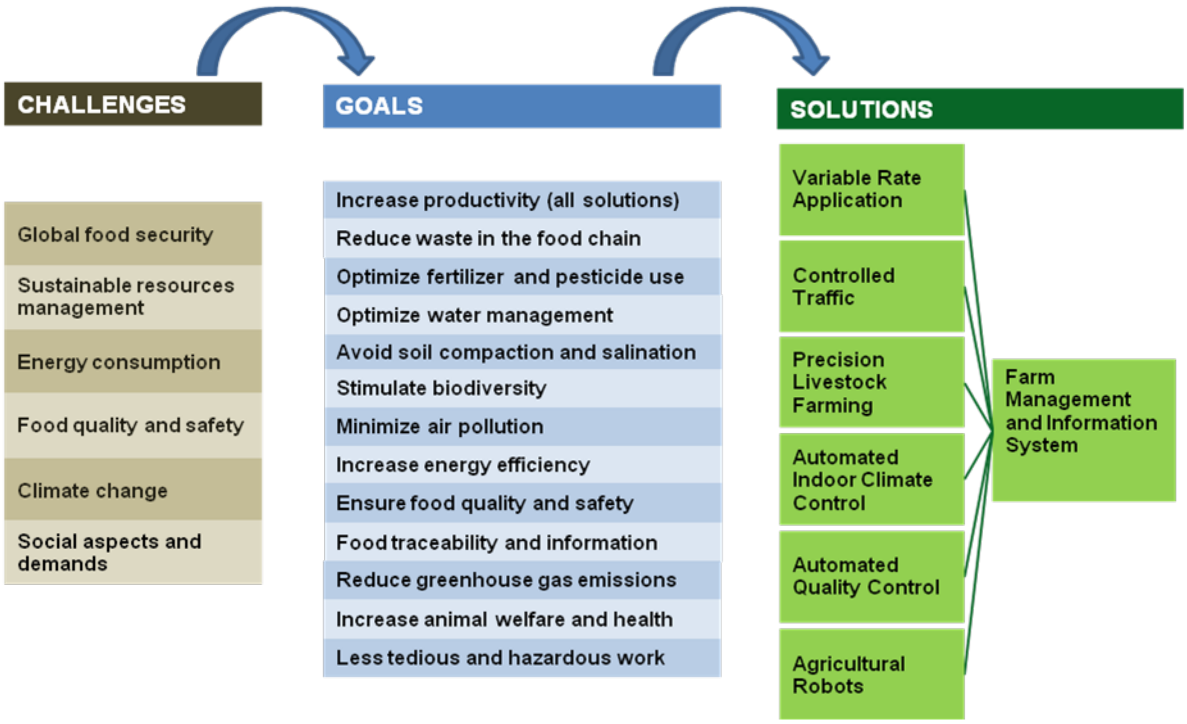

Figure 1: Challenges, goals and solutions for a sustainable European agriculture, identified by ICT-AGRI.

All solutions mentioned above have the potential to increase the production efficiency with regard to production factor (input) and productivity (output). In combination with the reduction of waste in the food chain this is essential to ensure global food supply for future generations.

To produce more food from the same area of land should not be associated with extra negative impacts on the environment. A sustainable management of natural resources aims at optimizing the efficiency of production factors (e.g. fertilizers and pesticides, water, soil) to reduce negative environmental effects. Related goals are also the avoidance of soil compaction and salination, the minimisation of air pollution by reducing emissions and the stimulation of biodiversity. ICT solutions contributing to these goals are Variable Rate Application of fertilizers, pesticides and water as well as Controlled Traffic.

Controlled Traffic Farming can also help to overcome problems related to energy consumption and climate change. The controlling of field operation traffic increases energy efficiency and reduces energy demand (including use of fossil energies) and greenhouse gas emissions from agriculture. The use of energy saving systems for Automated Indoor Climate Control pursues the same goals.

Automated quality control is essential to ensure food quality and safety (e.g. less cells and bacteria, less/no residues of pesticides or pharmaceuticals in plant and animal products). ICT solutions having an impact on product quality and safety are Variable Rate Application, Precision Livestock Farming and Automated Indoor Climate Control. Advanced Farm Management and Information Systems (FMS) are needed to optimize the information flow between farm software applications and between stakeholders to improve traceability throughout the food chain.

Social aspects and demands will keep on playing an important role in the European agricultural sector. Precision Livestock Farming and Automated Indoor Climate Control contribute to animal welfare and health. Animal specific feeding, milking, monitoring and housing results in prolonged productivity. The use of Agricultural Robots for animal and plant production processes improves work place ergonomics and labour efficiency by undertaking tedious and hazardous work or by better human-machine interfaces.

Summarizing, there are many points where ICT applications help to pave the way towards more sustainable agricultural production systems and have the potential to change and improve agriculture. Beyond the technological aims the ambitions of the SRA are to integrate these technical solutions in an overall approach to be sure that they are on the sustainability way and that all the conditions are gathered for a realistic dissemination of them to aim a large scale eco-efficiency.

1.3. Goal and structure of this action plan

The goal of this action plan is to define actions on how to stimulate the implementation of the Farm Management and Information System research/innovation topics. The main focus for the action plan is to form the basis for the second ICT-AGRI-2 call in 2016 that is focused on Farm Management Systems. The challenge for the action plan is thus (1) to first define the main challenges in information systems based on the SRA topics, (2) to define the specific research & innovation topics in Farm Management Systems in more detail, (3) to define actions to be taken for our second call that is focused on the information system topics, and (4) to define other actions that can be taken to promote Farm Management Systems via existing instruments. These parts are described subsequently in the next chapters of this document.

2. Main challenges in Farm Management Systems

The implementation of the SRA will be done in 3 yearly action plans. Per yearly action plan, a subset of the 7 solution domains of the SRA is selected to form the specific scope for that year. For the second action plan, targeted to 2016, the scope was chosen to be on Farm Management Systems. One of the main reasons for this selection is that Farm Management Systems are important for the operation of the farm itself, but also make the connection with the supply chain up to the consumer. Thereby, these systems contribute to one of the global challenges namely to global food supply in a secure, efficient and effective way. More specifically, the main goal of Farm Management Systems is to contribute to solving the following main global challenges:

- Increase support of craftsmanship and enterpreneurship
- Farmer to farmer and farmer to community cooperation
- Smart farming
- Increase food safety and secure supply
- Value creation along the supply chain
- Reduce human labour force

A Farm Management System (FMS) is defined as the backbone system for all other ICT and robotic solution domains. FMS provides a common user interface across solution domains and a repository for farm information (fields, crops, buildings, facilities, inventories, animals, past operations, goals, quality measures etc.). FMS also includes tools for communication and information exchange with external bodies, e.g. providers, food chains and authorities. An efficient FMS is based on defined agronomic information, which effectively reflects agricultural production and the inherent decision processes. Decision Support Systems (DSS) provide information for economically and environmentally appropriate farm management and thus help the farmer in his daily work. The necessary information exchange requires interoperability between products from different vendors.

Data concerning farm inventories, events and operations are mostly entered manually. This time-consuming and error-prone work has to be replaced by automated information collection and storage. Barcode or RFID readers could be used to maintain inventories of on-farm storage. On-farm cabled or wireless networks could be used for internal information exchange and web-based approaches for farm management would allow the integration of decision support systems (e.g. crop suitability models, early warning systems for pests and diseases, sustainability check, full lifecycle assessment) to increase the efficacy of the system.

The FMS of tomorrow will be a modular system. Farmers need to be able to choose which modules or services they want to use. Some of the services will be for free, whereas others will require subscriptions. These services need to work together, integrate and interoperate as one transparent FMS. A desktop client could synchronize the online and the desktop databases to integrate all necessary services. But interoperability concerning common software components can only be obtained when research institutions, end-users and manufacturers are prepared to work together (co-create, co-innovate). They have to agree on certain (open) standards (process models, information models and semantics, messages, code lists etc.) and should overcome problems of information privacy and reluctance to share information as well as social and cultural barriers.

The ultimate success of a Farm Management Systems is measured by its adoption and use at farm level. The level of uptake varies dramatically between farm enterprise, farmer age, region and level of technology development. Research should focus on the background reasons for these differences and should come up with specific guidelines around FMS development adapted to enterprise, region and system. Demonstration of value is an important precursor for the implementation in practice. Investments and operation costs of complete and efficient FMS are considerable and farmers will expect real business improvements with regard to income development and working time requirements. In addition, the interfaces must be as easy to use as possible, so that the farmer is able to manage the system without problems. This is a prerequisite for adoption of all new technology.

Based on this global description of Farm Management Systems, we distinguish a few subdomains in that area based on the main objects to be managed on the farm and beyond. Thereby, we distinguish the following 4 subdomains:

- Precision Crop Management (PCM)
- Precision Livestock Management (PLM)
- Building and Facilities Management (BFM)
- Food Chain Management (FCM)

In each of these processes information is being collected, aggregated, analyzed, exchanged and provisioned on the farm as well as with other stakeholders outside of the farm in order to best support these processes. In the sections below, the main challenges for these subdomains of Farm Management Systems are briefly described and the relations with the global challenges are given.

2.1. Precision crop management

Precision crop management is concerned with the management of information that is needed to do precision crop farming. An important process in this domain is the optimization of inputs to sub-areas of fields in order to increase the total efficiency as well as to eliminate or reduce the negative effects on the environment. One focus of precision crop management is the site-specific application of fertilizers, pesticides or water. The information to be used for this process is based on application maps or on real-time sensor measurements. It includes sensors, sensor-information and decision algorithms for variable rates, decision support systems and tools for creating application maps as well as auto-guidance systems and spreaders for variable rate application. It requires empirical information on the current state of crop and soil, at a suitable spatial resolution, measured by sensors or human observations. This information must be interpreted to generate decisions for optimum variable application rates. Therefore automated information exchange between different applications and components is essential.

Another important process is the geo-positional control of field operation traffic to optimize yields and input (including fuel and labour) and to reduce negative environmental impacts. Thereby, the focus is on reducing the total amount of fertilisers, pesticides and water applied to fields by using GPS guided machinery. This includes decision support to minimize traffic and soil-compaction, auto-guidance, fixed tracks-guidance and fleet-management. It requires agronomic knowledge relating crop development to field operations. The operation and traffic planning tools as well as real-time monitoring and steering tools call for comprehensive information exchange and interoperability.

2.2. Precision livestock management

Precision livestock management is concerned with the management of information that is needed to do precision livestock farming. This includes the improvement of profitability, work ergonomics, and animal health and welfare based on sensor measurements and advanced information and communication technologies. Also food safety and quality, efficient and sustainable animal farming and acceptable environmental impact of livestock production are important goals of precision livestock farming. Important processes in this domain are feeding, cleaning and milking, and sensor-based detection of animal status regarding breeding, health and welfare, and handling of farm animals. Rational management of greenhouse gas (GHG) emissions from animal operations is still a major challenge. Disease risk management and modelling is an important process too. Early detection of health problems will reduce the risk of pharmaceutical residues in meat and manure.

Several innovative automation technologies for precision livestock farming are on the market. Some, like au- tomatic milking and feeding systems, are well established and work at a high degree of functionality and reliability. Others, especially sensors and analysis algorithms, have not yet reached that development level. Such systems should always consider the variation between individual animals. Monitoring and decision support systems allow efficient herd management. Tighter monitoring of individual animals should lead to higher production efficiency and thus a lower environmental footprint per kg of produced product. Optimal route assessment tools in case of animal disease outbreaks and dispersion modelling for diseases are needed. Full integration of precision livestock management should also include animal handling infrastructure. Integrating facility information with animal information would be a very powerful way of improving profitability and sustainability.

2.3. Building and facilities management

Building and facilities management is concerned with the management of the buildings and facilities on the farm. One of the important aspects of this domain is indoor climate control. Information management by automated indoor climate control systems should help to reduce energy consumption and GHG emissions, and improve the environment in buildings for livestock and greenhouses. This contributes to healthy animals and livestock-friendly housing systems. Optimum indoor climate for greenhouses and animal buildings is based on sensor measurements and automated regulation. This requires knowledge on reactions of plants and animals to temperature, light and air (including humidity and CO2 levels) and embraces the automated control of these components and the adaptation to outdoor climate.

Complete climate systems are available both for greenhouses and the major farm animal species, but they often lack adequate systems for reducing energy consumption and CO2 footprint, especially in compliance with animal health and welfare. Information collection, aggregation and analysis are important aspects of innovative climate systems that are easy to use without reducing the potential of the system. This includes checking functionalities (for air flow rate, temperature, pressure difference etc.) as well as controlling functionalities (flow rate as a function of indoor gas concentrations such as CO2, NH3, etc.). Smart control of ventilation will help to facilitate optimal control of emissions. State-of-the-art integrated or coupled heating-ventilation systems which already exist should be adopted in agriculture. It is no longer feasible to heat a room with one installation and ventilate the same room with another, unrelated installation. Recovery of energy is also a crucial aspect that might be enhanced by automated probing and controlling. Automated natu- ral ventilation is considered to be an ener- gy-efficient technology to control the indoor climate. If this can be adapted to surrounding weather conditions a reduction of GHG emissions is possible.

2.4. Food chain management

Food chain management is concerned with the information flow throughout the food chain that is necessary to improve on food safety, tracking and tracing, but also on food integrity and quality. This information flow is accomplished by sensor measurements during harvest, transport, storage and delivery to the food chain. It requires knowledge and information on reactions of food and feed to harvest, transport and storage conditions. It also includes quality-measuring sensors in food and feed, information exchange with the farm for alarms and documentation, and control loops for automatic regulation of quality maintenance. Information exchange with governments for quality inspection and monitoring is an important part of food chain management and control. This should be based on standardizaed indicators that are transparant and well-documented in order to be used as benchmarks.

Consumer confidence depends on trust in good product quality and safety. Therefore inspection principles for ensuring traceability of quality and origin as well as bioorganic compliance should be a priority to guarantee satisfied consumers and higher retail prices. Reactions of food and feed to harvest and storage conditions (relations to climate control) are important challenges in this domain. These are determinative factors for the later food and feed quality, influencing the taste, the concentration of health components and the safety of the end products. Innovative sensors in plant production, for example, should monitor both maturation stage and nutritional or organ-oleptic quality of fruits and vegetables. This will help to optimize agronomic practices and to identify the harvest time as a function of the required quality level. In livestock production, further developments such as new sensors for determination of additional milk parameters (lactose, urea, progesterone, ketone bodies, enzymes etc.) would improve quality control. Water availability and quality are becoming limiting factors for agriculture, hence enhanced management and optimal information gathering and exchange is required. Today sample-based quality control is common practice, but future technologies should enable close monitoring of individual product quality. A crucial requirement is the permanent information exchange with Farm Management Systems for alarms, documentation and automatic quality supervision and regulation. ICT products from different vendors should be compatible, ensuring in-farm efficiency and also for exchange of information and traceability along the food chain.

3. Specific research and innovation topics for FMS

The previous chapter showed the main challenges in Farm Management Systems and in its subdomains. The SRA described the needed improvements for this area as identified by the end of 2012. In the meantime, the field of Farm Management Systems has further developed especially in the context of future Internet developments and its use for the agrifood sector. When combining all these developments, the following list of 4 main types of research and innovation topics for Farm Management Systems can be drawn up:

- Information collection mechanisms
- Information aggregation and analysis techniques
- Decision-support and exchange of information
- Implementation and adoption of Farm Management Systems

Each of these 4 main R&I topics are important in various ways for the 4 subdomains of Farm Management Systems. The figure below depicts a matrix that will be used as a vehicle to describe the specific needs per topic per subdomain. Examples of specific needs are given in each cell. Note that these are not complete or covering all the needs.

Primary Domain	**Supported Subdomains**	**Collection**	**Aggregation and analyses**	**Decision-support and exchange**	**Implementation and adoption**
Farm Management Systems	Precision Crop Management **PCM**	Remote sensing Drones Smart Sensors Improved spatial sampling	Techniques for pattern recognition Information standardization Improved geospatial analysis	Weather-based decisions Decision-making crop type vs land area Nutrient management Pest/ disease monitoring Planting, growing, harvesting and storing	Platform for modular implementation User-friendliness Involvement of farmers and other stakeholders Demonstration and 'Test beds'
	Precision Lifestock Management **PLM**	Remote sensing Drones Smart Sensors Improved spatial sampling	Techniques for behavioural pattern recognition Information standardization Improved geospatial analysis	Feed Quality management Health managment Reproductive Cycle management Nutrient management Pasture management Processor to Client communications	
	Buildings & Facilities Management **BFM**	Smart sensors	Improved data gathering and interconnectivity	Operations and planning Energy Management Quality Control	
	Food Chain Management (Automated Quality Control) **FCM**	Smart sensors	Improved data gathering and interconnectivity Improved risk analysis Improved geospatial analysis	Holistic chain approach Public health Reporting to government	
	All subdomains	Interoperable and compatible sensors Network of sensors	Data sharing/storage Big, semantic interoperable data Data analysis and pattern detection Data ownership	Self-learning algorithms Data visualization Multivariate approach	

Figure 2: Research and innovation topics per subdomain of FMS.

In the sections below the needs for these 4 main R&I topics are worked out in more detail and specific examples are given for each of the subdomains where applicable. Eventually, projects on FMS should combine these four topics into a holistic approach.

3.1. Information collection mechanisms

Information collection mechanisms are concerned with the collection of data from various distributed sources by various different means. Thereby, we can distinguish between sensor data measured by farm equipment on plants, animals, etcetera but also remote sensing via satellite or weather stations. In addition, various other data sources can be used to collect information that is important for farm management. A last interesting innovation topic in this sense is the alignment of the information from various sources via the use of information standards. This research and innovation topic has three different subtopics that follow below.

Access to sensor data

The challenge is:

> to collect data from sensors of various types to be used further down the information chain using sensors on farm equipment, plans, cows, satellite images and weather.

Today modern farms, both in arable farming and precision livestock farming, are loaded with all kind of sensors. Farmers and other stakeholders must be able to collect this data in such a way that the data is directly usable for further integration and decision-making. This calls for new collection mechanisms and ways to make measured data accessible in a secure and standardized way.

Examples of access to sensor data are:

- In PCM, wireless sensor networks to monitor pest counts to automatically activate and disrupt the mating patterns of pests
- In PCM, embedded wireless devices and soil monitoring systems for farmers to measure moisture, detect leaks and more efficiently manage energy usage, all in real-time
- In PLF, wireless sensor networks for lifestock cow management
- In BFM, in sensor data to control micro-climate conditions in greenhouses
- In FCM, collection of data on the tracking and tracing of products and environmental parameters.

A restriction for this topic is that the research and innovation should be built on widely available mobile networks and disseminated via mobile phone; monitoring and electronic controls to help farmers continually analyze the quality of their products.

Data collecting from various sources

The challenge is:

> to collect data from various sources other then sensors to enhance automated analysis and decision-making, e.g. data from crowd sources, such as pictures and even social media.

Besides measuring sensor data at the farm, in the supply chain or via remote sensing, a lot of information can nowadays also be gathered via other various data sources. Social media can be an interesting source for data to be used for better farm management. In addition, small private measurement systems of citizens outside the farm and the supply chain can give interesting input for farm management. This can be captured under the name of crowd sourcing. This calls for new mechanisms to collect this crowd data and convert it to such a format that it can be used for analysis and decision-making.

Examples of data collection from various sources are:

- In PCM, crowd sourcing for verification of local weather information along with soil humidity
- In PCM, tracking pest and disease outbreaks to help in identification and removal of different types of weeds through crowd sourcing
- In PLM, compiling field plans for suitable grazing through crowd sourcing
- In PCM and PLM, updating existing geospatial data with pictures and video recorded on mobile devices using GPS and input the field sampling information
- In BFM, automating everyday farm operations and real-time monitoring and data analysis for smart decision making, day-to-day and season-to-season.
- In BFM, enabling farmers to program exactly what and where each piece of equipment will plant, fertilize, spray and harvest for an area as small as one by three meters
- In FCM, crowd sourcing to allow access to remote farmers and their inputs
- In all subdomains, collection and reporting of information on crises, disturbances, and other events by mobile phone and updating the information on Google Maps.

Information standardization

The challenge is:

> to standardize the information measured by sensors and collection systems to be able to compare output equally.

Better compatibility between systems on and outside the farm is the goal here and to stimulate the definition, implementation and usage of information standards for data exchange between these systems. Information elements coming from different sources that have intentionally the same meaning can be named slightly different and are therefore difficult to compare and combine. Thus, standardization of information to be used is necessary.

Examples of information standardization needs are:

- In PCM and FBM, insight and automation to enable farmers to program exactly what and where each piece of equipment will plant, fertilize, spray and harvest for an area as small as one by three meters.
- In FCM, combine products from different farmers for collective buying and selling
- In PCM and PLM, definition of good agricultural practices based on standardized criteria
- In FCM, bringing data from multiple sources together to allow farmer access to information, promoting market access and farmer collectivization
- In PCM and PLM, embed connectivity into agricultural equipment through fleet telematics solutions, for farmers to track their machines and analyze actionable data in real-time.

3.2. Information aggregation and analysis techniques

Information aggregation and analysis is concerned with the use of data collected at various distributed sources. This data needs to be combined and aggregated such that it can add value to the farmer. Simply combining data sources is already an improvement in the information provisioning to the farmer. Additional analysis of this combined big data can add even more value by enabling better decision-making. This research and innovation topic has three different subtopics that follow below.

Big data analysis for pattern recognition

The challenge is:

> to define and operationalize an infrastructure to analyse and visualize the combination of large amounts of data from various different sources for farmers.

Today modern farms, both in arable farming and precision livestock farming, are loaded with all kind of sensors. Clients must be able to connect with this data, but also data coming from multiple sources in and outside the farm should be integrated and combined. Based on these large amounts of data from different sources that are being combined, it is possible to perform analysis on this data for decision support making. Examples of applications of big data analysis are:

- In PCM and PLF, the detection of anomalies and patterns in the data over place/time with respect to a certain soil concentration or animal behaviour gives insight in possible actions and guidance of the preparation of the soil/crop or the animal with respect to diseases or other treatment.
- In PCM and PLF for analysis on existing information sources on the farm to learn from historic data on crop and/or cattle.
- In PCM and PLF, satellite data coming from open data sources from government or open weather information sources as a basis for decision-making.
- In PCM, for deciding on crop type versus land area
- In PLF, for looking for patterns between feed and milk production
- In BFM, for analysis of CO_2-efficiency of buildings
- In FCM, analysis of historic or forecast of demand/supply for products.

A restriction for this topic is that the research and innovation should not be targeted towards the development of new big data analysis techniques and algorithms, but apply existing analysis techniques like text mining methods and tools, data clustering techniques, machine learning, data analysis workflows and data mining in the agricultural domain.

Semantic alignment for aggregation of data

The challenge is:

> to define mechanisms that enable the semantic mapping of similar but slightly different terms in the various data sources in order to combine them in a semantically correct way.

In the agricultural domain, a lot of systems are in operation that deals with information of different origin but with similar nature. When integrating and connecting these systems, information elements in different systems might have the same meaning but are represented by slightly different terms, e.g. by synonyms. In order to combine these data elements in a semantically correct way, a semantic gap has to be filled, either by standardizing the terms or by defining a mapping between them. Examples of solutions for semantic alignment of different data-sources are:

- Define knowledge models and ontologies for data in existing data sources using existing ones like AgroVoc and AgroRDF to open them up for broader use.
- Common datamodels for mapping between existing sources in order to enable more broader answering of big data questions on crop and livestock management.
- Use of methods for automatic enrichment of data sources with metadata.

A restriction for this topic is that the research and innovation should not be targeted towards new methods and tools for semantic alignment, but applying these tools to the agricultural domain by buiding on top of existing vocabularies and ontologies in the domain, such as AgroVoc, AgroRDF, GoodRelations, etc.

Information ownership

The challenge is:

> to deal with ownership of data, licensing for data usage, define business models for data sharing, cost-benefit analysis for the aggregation of data and allow for anonymous as well as open data.

With respect to data ownership, there is a naïve belief that data belongs to the farmer but this is often not the case if the farmer has signed a typical user agreement. Innovation may be stifled if data is kept locked up in databases to which there is no access or access agreement. For example, feed companies do not have to declare the exact composition of feeds they supply but that data is essential for some nutritional models to operate successfully. Examples of issues and necessary innovations are:

- Data collected for supply chain management purposes or for machine evaluation purposes may not belong to the farmer or even reside on his computer system.
- Data curation agreements where the data is held by a third party on behalf of the farmer and made accessible for app developers to develop apps to integrate systems.
- Farmers want to control whom can see and use their data. The IT sector has mechanisms and tools for the development of systems that ensure this. These should be used in the agricultural sector to improve innovation on this topic.
- Access to good quality public data.

Several hurdles in sharing of (open) data have to be taken. Farmers are reluctant to give access to their farm management and sensor data, including data on variation within soil, crop and livestock. They want to control who can see and use the big data. Only a few farmers see that this big data can be used as a sign of good agricultural practices.

3.3. Decision support and exchange of information

In complex environments like agriculture, the value-adding potential of using decision support systems based on automatically processed sensor data is very high. Due to the continuing increases in farm scales, making well-informed management decisions becomes increasingly difficult without using sensors and ICT. Current sizes of farms make manual checking of crop and livestock health and growth a daunting task. In order to keep farms manageable, data-driven ICT-based decision support systems will increasingly replace this manual work. These systems can perform a variety of tasks, which calls for new decision-support tools and algorithms. In addition, the collected and aggregated information on the farm and other stakeholders in the chain need to be exchanged with the government for legal and inspection means. Thereby, it is important to use the same indicators and definitions or benchmarks in order to measure and compare information from different sources correctly. This research and innovation topic has three different subtopics that follow below.

Decision support systems

The challenge is:

> to build decision support systems that add value based on automatically processed sensor data.

As an increasing amount of data becomes available by collection, aggregation and analysis, better decision-making is possible to steer the day-to-day operations on the farm. Automatic processing and analysis of this data gives the opportunity to use real-time decision-support models for the operational tasks of the farmer. In addition, better visualization of the tasks at hand and the results of the decision-supporting process is made possible. In this context, it is important to indicate that such systems are meant to be supportive for the farmer and not for automatic decision-making and actuation. Examples of areas where decision-support systems are needed are:

- In PCM and PLM, due to the continuing increases in farm scales, making well-informed management decisions becomes increasingly difficult without using sensors and ICT.
- In PCM and PLM, current sizes of farms make manual checking of crop and livestock health and growth a daunting task.
- In PCM and PLM, data-driven ICT-based decision support systems for a variety of tasks, e.g. early warning systems, economic decision support, provision of traceability of farm products.
- In PCM and PLM, decision strategies for operation and dealing with risks by standardizing operating procedures and taking preventive measurements to deal with risks

Standardization of high-quality data

The challenge is:

> to standardize data for efficient exchange between farms and all other stages/stakeholders in the agricultural supply chain.

Information gathering and decision-support for the farmer is one side of the coin. In addition, information exchange with other stakeholders is an increasingly important task for the farmer, as he/she is obliged to provide information towards government inspection on the one hand and towards other stakeholders further down the supply chain. When exchanging such information, again the need for standardization arises as only then the information can be combined and aggregated without comparing apples with oranges. Examples of standardization needs for high-quality data are:

- In PCM and PLM, a good choice of data platform (preferably an existing, public platform) should be made on which standardization can be based in crop farming and livestock farming.
- In PCM and PLM, standardization should focus on high data quality, i.e. the provision of adequate metadata for the various datasources and information systems already in use in crop and livestock farming.
- In FCM, information interoperability for traceability of food products in the supply chain
- In FCM, data exchange with stakeholders in government, research and service providers for the collection of information for reporting purposes.

Indicator development

The challenge is:

> to develop algorithms in order to provide for correct decision support based on indicators that encapsulate multiple criteria.

In order to make decision support based on a broad view of parameters, it is important to use a set of criteria that are commonly accepted and cover various aspects of the farm and its environment. Thus, multiple criteria sets are needed. This calls for the development of indicators and algorithms in order to provide for correct decision support. These indicators should focus on multiple criteria:

ideally economic, environmental and social criteria. These indicators should be transparent and well-documented. Examples of aspects of indicator development are:

- In all subdomains: focus on multiple criteria: ideally economic, environmental and social criteria in order to take into account all aspects of the farm, crop/cattle, operations and buildings/facilities.
- In all subdomains: make these indicators transparent and well-documented, so they can be used for all products and by all stakeholders across the supply chain.
- In FCM, compliance with local laws on traceability and data exchange is required.

3.4. Implementation and adoption

Besides the three innovation topics aling the information processing chain on information collection, aggregation, analysis, decision-support and exchange there is a fourth topic that is more of a generic and horizontal nature. This is how to support and enable the implementation and adoption of existing and new IT components into a farm management system.

The current situation in Farm Management Systems is one of island automation with a couple of main bottlenecks:

- Small-scaled, isolated software development focusing on small parts of farm business
- National/regional focus and cultural differences, which means that an application in one country is difficult to use in other country
- Poor interoperability between various systems at farm level and supply chain network
- Poor European standardization of data messages and reference process models

The current trend is towards small apps for all kind of dedicated purposes that can be used through the Internet. On the one hand this makes it easier to use (e.g. on smartphones, tractor terminals, etc.) but on the other hand it just increases the main issue of interoperability. It gets even worse when we see the data exploding by the introduction of numerous sensors in agriculture.

In practice this means that farmers have to use a number of different apps/applications to cover the full range of a business process (e.g. from land tillage to harvesting a crop) that are hardly collaborating with each other. This leads to insufficient and inefficient farm management support with a lot of annoyances (e.g. filling in the same data in each app all the time). Ultimately, this will hamper adoption of FMS solutions.

In many industry sectors Enterprise Resource Systems (ERP) were introduced to overcome these challenges (e.g. SAP). A problem is that these systems have become very big and complex and therefore usually too expensive for farmers. In the meantime ERP vendors have moved towards more light and flexible versions of their systems, which could make them applicable to farming. There were also several ERP-kind-of-systems introduced specifically for farming or current FMSs have moved into that direction. Nevertheless, it will always remain difficult (and even practically unfeasible) to support all aspects of farming by one system. Moreover this would probably also lead to monopolies of large ICT companies, which is also not desirable. Hence, for the situation in agriculture, the step of ERP systems can best be skipped and a direct move towards an open architecture is preferred. In such an open architecture many applications can easily collaborate with each other to support all kind of business processes in farming. This is depicted in Figure 3.

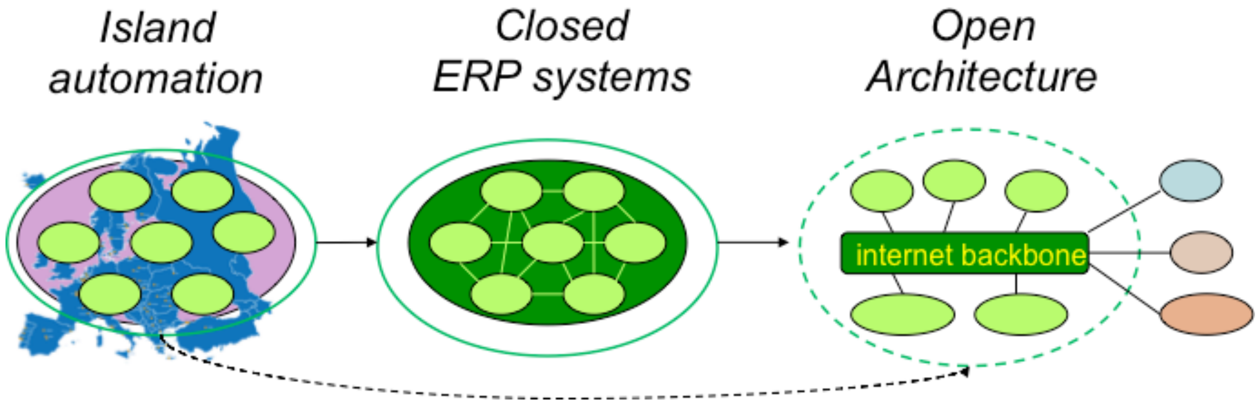

Figure 3: From island automation to open architecture by skipping closed ERP systems.

This means that a kind of 'internet backbone' should be introduced that is able to support or facilitate the collaboration between different apps. As the picture suggests these can be apps within the agricultural domain, but possibly apps from other sectors that could be useful for farming can be included. For this purpose, three developments should take place:

1. Platform for modular, smart services and applications
2. Open standard interfaces
3. Requirements on components and implementations

These are elaborated in the following subsections.

Platform for modular, smart services and applications

A more holistic approach on systems thinking and chain thinking should be used. Starting point should be that data and information from process level on individual animals, and management units within parcels plays a key role in generating value. This data and information exchange can be simplified and supported by learning from ICT developments in other sectors. A shift is needed from R&D on development and testing of individual sensors towards R&D on real daily management support systems for farmers and other chain partners using innovative ICT tools.

Platforms can be established as new developments designed to serve business collaboration between providers of apps and data, or platforms can evolve by transformation of existing FMSs to be capable of integrating third party apps.

Figure 4 provides a possible architecture of a platform for modular, smart services and applications. The basic assumptions are that:

1. There are existing systems (e.g. FMSs, sensors, etc.) that produce data and other external data that are involved in farm management.
2. There are actors that play various roles in the platform (e.g. app/service provider, app developer, etc.) and users of ICT components and services that are offered through the platform.

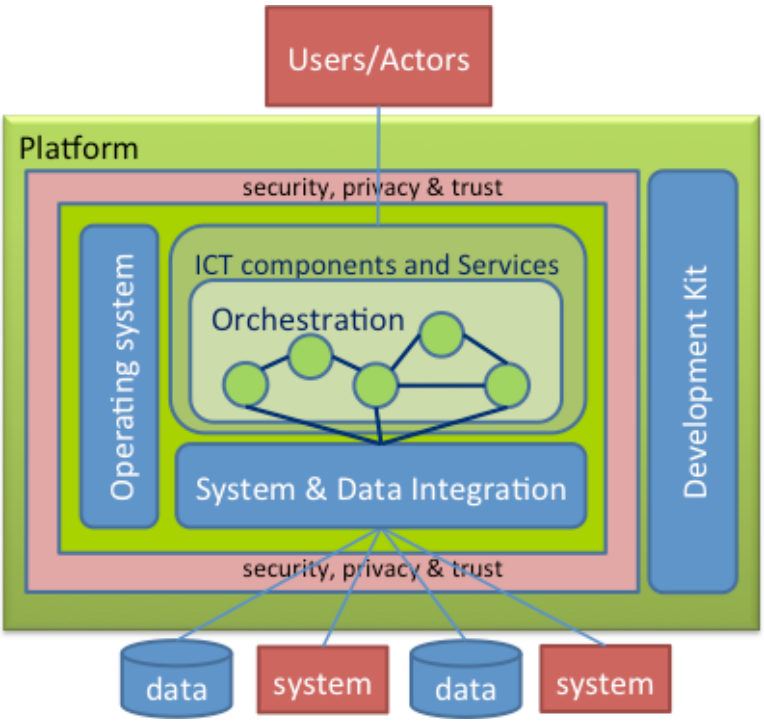

Figure 4: A possible platform architecture for FMS components.

The following components are then needed:

- *Security Privacy & Trust (SPT)*: layer to assure that all data is safely exchanged
- *Orchestration*: to facilitate a smooth collaboration between various ICT components and services
- *System & Data Integration (SDI)*: to assure that the external systems and data are integrated – according to standards – so that smooth communication with external systems and data is guaranteed
- *Operating System*: to make all platform components work together
- *Development Kit*: to support developers in developing and configuring ICT components and services.

This architecture is based on an event-centric approach, which means that a business process is first described in terms of events and messages between components that are involved. Currently this might seem to be too complex to be realized in practice. It requires a high effort and commitment from developers to comply with the standards of such a platform and from a business perspective it is difficult to persuade current platform providers to move towards such an open platform architecture. A stepwise, bottom-up approach is proposed in which open standard interfaces and web-based approaches play an important role.

Open standard interfaces

Open standard interfaces can be defined at 4 levels and can be considered within one enterprise (intra) and between enterprises (inter), as depicted in Figure 5.

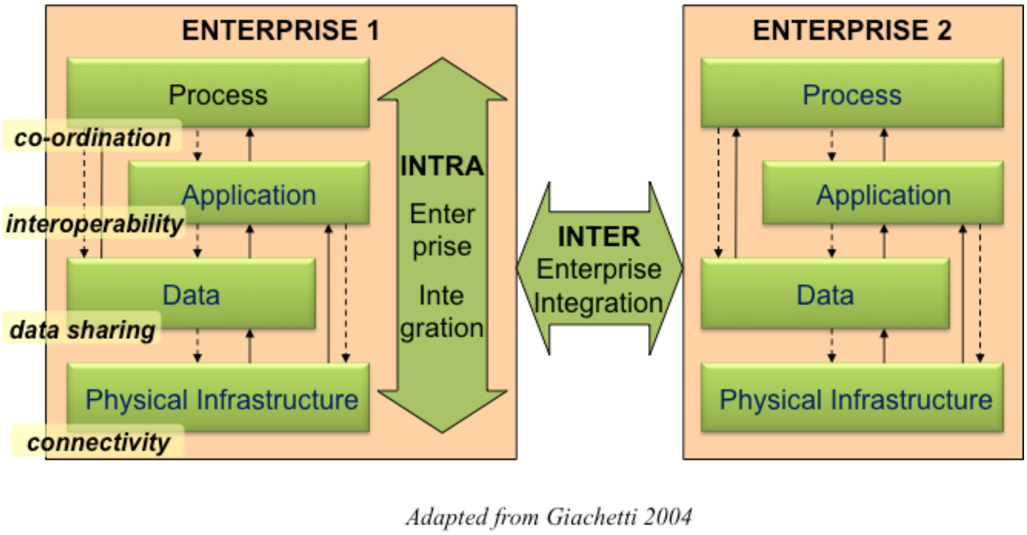

Figure 5: Open standard interfaces for FMS components.

1. Basic technical foundation is integration of technical devices: computers, machines, but also products. Important are network and transport protocols such as TCP/IP and HTTP. Also interface standards are important: PLC's for machine accessibility and product identification standards such as barcode scanning and RFID.
2. Next level is about data sharing, especially standard message formats such as XML, common data definitions such as the GS1 article coding system, and standard messages such as in EDIFACT, and ebXML.
3. Based on this technical foundation and data standards, it is possible to integrate applications. Here the focus has shifted successively from point-to-point interfaces, to implementation of big integrated systems such as ERP, to web service based integration. Web services are autonomous software components that can be connected via internet. The format, interfaces, and communication is standardized.
4. Last level is process integration, the alignment of tasks by coordination mechanisms. This is the goal of the other integration types. In Service Oriented Architecture, business processes can be modelled using BPMN and described in XML and BPEL. This makes it possible to manage the sequence and interaction of webservices driven by business processes. Further, for this level there are several reference models that provide recommended process models for specific domains. Examples are S95 for production control, ERP reference models e.g. of SAP and Infor (formerly Baan) and the SCOR model for Supply Chain Management.

The arrows between the different layers suggest a certain interdependency. Standardization at physical infrastructure level is required before you can standardize the next level and so on. For ICT-AGRI it could be proposed to set requirements at all levels.

Requirements on components and implementations

In order to strive towards an open architecture with ICT components for Farm Management Systems, the following hardware and software requirements need to be satisfied:

- Devices should comply with international standards (e.g. ISOBUS)
- Data messages should comply with existing national and international data standards
- Applications should have an open API so that other applications are able to collaborate

- Reference process models should be provided that describe farming business processes providing guidelines for configuration of different ICT components and services
- Easy-to-use user interfaces
- Web-based components for future IoT integration
- Farmers should be involved in application development
- Platforms/applications should have a consistent business model
- Support for developers and service providers in application configuration and integration
- Focus should be on harmonizing existing platforms and standards instead of developing new ones (FiSpace, Farm365Net, Datalab)
- Compatibility should be ensured with products from other/different suppliers and demonstrated via plugfests
- Contribution to standardization is welcome

4. ICT-AGRI-2 Joint Call in 2016

The research and innovation topics described in the previous chapter form the basis for a joint call of ICT-AGRI-2 in 2016. For this call project proposals will be invited that can focus on the topics in the cells of the matrix depicted in Figure 2. Within these proposals it is expected that focus will be on the ICT part of the challenges. This chapter briefly describes the instrument that is used in a joint call on the FMS research and innovation topics.

The 2015 ICT-AGRI Call was a traditional ERA-NET call: The ICT-AGRI national funding agencies committed a sum of money to a so-called *virtual common pot* for trans-national projects with at least three countries in each consortium. The word *virtual* relates to the rule that only partners from the same country or region can apply for grants at a given funding agency. The call was run in two stages, first pre-proposals evaluated by the funding agencies for formalities and relevance, and then full proposals evaluated by independent experts for quality and expected impact. The call took about a year from launch to contracts with funded projects.

The involvement from industry was smaller than expected for a call with topics quite close to the market. This raised considerations within ICT-AGRI about a simpler and faster callprocedure, which could be more attractive to in particular SMEs.

The European interests and investments in RTD in ICT and robotics for agriculture have grown substantially in 2015. Several countries have large national programmes for research and development in ICT and robotics in agriculture. Three Future Internet accelerator projects have supported more than 100 SMEs for development of Smart Farming applications. Horizon 2020 is launching new calls within robotics and Internet of Things.

By the end of 2015 it became obvious that there would not be sufficient commitments from funding agencies to a similar call in 2016.

ICT-AGRI will in 2016 launch a call for transnational partnerships based on national and regional funding as usual, but without prior commitments from the funding agencies. The partners must secure their funding directly from the national or regional agencies. The ICT-AGRI Partnerships is also open for exiting projects.

The ICT-AGRI Partnerships relates to the scope of the ICT-AGRI Call 2016 (Farm Management Systems) by requiring partnerships to produce Smart Applications prepared for inclusion in FMS or to produce new tools and knowledge for implementation and adoption in FMS along the lines described in section 3.4.

4.1 ICT-AGRI Partnerships

The purpose of ICT-AGRI Partnerships is to generate added European value, and international value, from nationally or regionally funded projects. Partnerships are intended to increase the compatibility and adaptability of agricultural Smart Applications to local farming conditions as well as local Farm Management Systems (FMS). The overarching goal is to promote uptake of Precision Farming and sustainable agriculture.

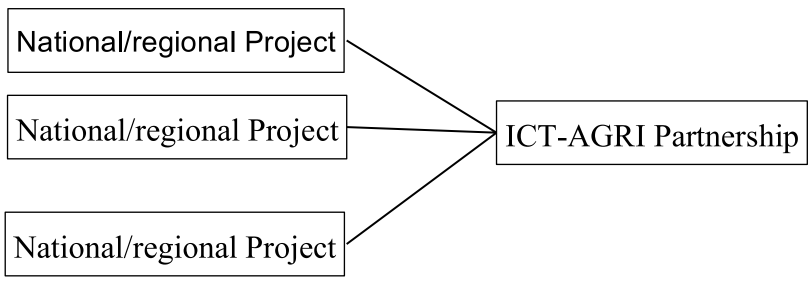

Fig. 6 ICT-AGRI Partnerships

ICT support to European farmers is spread over a large number of FMS operators including extension and advisory services, software companies, public services, manufacturers and food chains. The compatibility between ICT products from different operators is generally low. The capabilities and incentives concerning development of new applications are generally weak. The result is a slow adoption of the rapidly emerging technologies within sensors and robotics. These technologies are rather picked up by innovative SMEs and research groups creating Smart Applications. The value for farmers of the Smart Applications depends however on compatibility with farm data organised and maintained by a FMS.

A possible way out of this dilemma is Smart Applications that can be easily implemented in existing FMS. The suppliers of Smart Applications will benefit from distribution through existing FMS by access to farm data and by savings on marketing and customer relations. The uptake by farmers can be expected to increase when a Smart Application is embedded in a FMS known by the farmer. Issues concerning data security and data ownership can be handled by the usual procedures of the FMS.

ICT-AGRI Partnerships will encourage the development and exploitation of third party adaptive Smart Applications. The implementation of a Smart Application into a FMS will usually require exchange of data between them. It will be an advantage if data exchange models comply to common rules. ICT-AGRI partnerships are therefore requested to share information about data exchange (protocols, standards, data schemes, ontologies, practical experiences, etc.) in the ICT-AGRI website. Partnerships may voluntarily share information about e.g. algorithms and internal data structures.

The eligible topics of ICT-AGRI Partnerships range from prototype development to implementation of commercial Smart Applications. Topics concerning methodologies for integration of Smart Applications and FMS are also eligible.

The ICT-AGRI Partnerships are established interactively in the ICT-AGRI website:

- Projects can seek partners and offer to be partner in a matchmaking tool
- Groups of projects can create and submit applications for partnerships
- Submitted applications are reviewed online by independent experts
- Funding agencies can allow or deny funded projects to enter partnerships

The projects in a partnership may be funded prior to the partnership application or may use the partnership application when seeking funding from a national or regional funding agency. Projects based on own funding or EU funding may also participate. Partners from at least three countries or autonomous regions are normally required. Partnerships with only two partners can be allowed when the partnership provides good reasons for this. Partnerships may include projects from countries not represented in ICT-AGRI, hereunder non-European countries.

Any Funding Agency can participate in the call given it allows funded projects to join ICT-AGRI Partnerships, hereunder non-European countries. Funding Agencies may contribute with projects funded by a regular funding programme or by a programme dedicated to ICT-AGRI Partnerships. It is expected that Funding Agencies inform about the possibility of joining ICT-AGRI Partnership.

4.2. Other instruments for a joint call

Besides regular projects of the types identified in the previous section, we also propose to use the following instruments to stimulate research and innovation on the topics described in chapter 3.

Infrastructure

The SRA identified a need for "experiments under various soil, faming and climate conditions in order to gather knowledge on the effects of CTF on soil compaction and regeneration, greenhouse-gas emissions, and plant/animal and yield development". It is felt that this can best be achieved through access to an integrated European infrastructure on different ecosystems. The ERA-NET consortium will analyse the extent to which this need is already being met through existing European infrastructure. If such a need is not being met, plans will be developed to catalyse the coordination of the relevant actors in order to ensure the availability of such facilities.

Plug Fest

Plugfests can be organized to bring together various suppliers of IT systems and solutions for FMS. At such a plugfest they can show that their solutions can be plugged to each other and that they are compatible and interoperable with each other. Users of their solutions are also present at such plugfests in order to present the requirements to the tests that are performed at the plugfest.

5. Other actions using existing instruments

This chapter proposes other actions that can be taken by the ICT-AGRI ERA-NET to further stimulate precision farming besides the ICT-AGRI call instrument. The focus of these actions is on precision farming and not on ICT and agriculture in general. With respect to the types of instruments, we distinguish between three types: aligning instruments, exploring instruments and investing instruments.

5.1. Instruments for aligning

The instruments for aligning are meant to be used for actions in which the SRA and the R&I topics on FMS are being aligned with other research programmes and initiatives.

Thematic Annual Programming

Means for aligning in the most cost and time-efficient way are being considered for developments that do not involve classic “calls”. In this case, based on the SRA and the identified R&I topics in FMS, mapping meetings, bibliometrics and advanced poster analysis, topics would be defined which are shared across many countries. Then, national programme managers would be invited to meet with eachother along with an ICT-AGRI steering group to define topics to be shared by any new national programme in this area. An item text (e.g. one page) can be included in each national programme participating on a voluntary basis. Then, after launching national programmes, a meeting would be organised with all projects working on a given item to discuss objectives, methods and expected outcomes. As part of this coordination, it might be possible to organise a database with project outputs. Following a pilot action of this type, programme managers would be invited to evaluate the effectiveness of this approach.

Teaming-up with other ERA-NETs

ERA-NETs are a means of implementing the alignment of research and innovation in various subdomains of agriculture among countries. There are a number of ERA-NETs that partly cover or are closely related to the topic of precision farming. One of them is the ERA-NET SUSFOOD and a means to align the work and topics with that ERA-NET is to organize a joint workshop. The ICT-AGRI 2 project consortium would like to organize a joint workshop with other related ERA-NETs, to make the concept of ERA-NETs more broadly known, and to generate more interest in upcoming ERA-NET calls. Therefore, the project consortium tends to send out invitations to other ERA-NETs to organize such a joint workshop. The event has to be relevant for all participating ERA-NETs, so it can only be determined after consulting the interested ERA-NET consortia. Possible ERA-NETs to align with are SUSAN and CORE Organic.

Partnerships with PPPs

The ICT-AGRI ERA-NET intends to interact and align with relevant European initiatives and in particular with related ICT-oriented Public Private Partnerships (PPPs). The aim is to avoid overlaps and duplications and when appropriate to work together to form synergies. In 2014, already a joint call has been realized with Future Internet PPP. Another PPP that is about to start is the Big Data PPP and a good alignment with this PPP in 2016 is necessary to get a good overview of the possibilities of Big Data and the current state of the art. This knowledge can be used to guide and assess the project proposals in our call in 2016. In addition, our ERA-NET can be useful to show good practices and use cases of the application of Big Data in precision farming. When appropriate and agreed by all partners, even a joint call with the Big Data PPP can be put in place with new funding.

5.2. Instruments for exploring emerging subjects

In the domain of precision farming, a number of emerging research areas are considered appropriate for exploratory events, which could develop into new calls and which will provide input into a subsequent version of the SRA.

Exploration and collaboration with EIP-AGRI focus groups

The EU has launched five European Innovation Partnerships (EIPs) in the context of the Innovation Union. European Innovation Partnerships are a new approach to research and innovation. EIPs help to pool expertise and resources by bringing together public and private sectors at EU, national and regional levels, combining supply and demand side measures. All EIPs focus on societal benefits and fast modernisation. They support the cooperation between research and innovation partners so that they are able to achieve better and faster results compared to existing approaches. One of the EIPs is the EIP-AGRI focusing on agricultural topics. The EIP-AGRI has set-up a number of focus groups on various topics, one with a focus on precision farming. The interaction between the ICT-AGRI ERA-NET and this focus group can be targeted to exchange the SRA and new research & innovation topics. Also the ERA-NET can be active in providing input to the operational groups that have to continue on the results of the focus group. This latter can be an action in 2016 to further elaborate on.

Joinup and collaborate with an ICT and Agri related conference in 2016

In 2015, we had a good collaboration with the EFITA/WCCA/CIGR 2015 conference in Poznan, Poland. For 2016, cooperation has to be sought with a more ICT-oriented conference at which an agricultural track is a pontential candidate. This conference has to be pinpointed. The ICT-AGRI 2 project consortium can then send one or more partners to this conference to present the concept, goals and accomplishments of ICT-AGRI and ICT-AGRI 2. In addition, ICT-AGRI can be active at the conference with organising an Interoperability Hack-a-ton in which suppliers of IT systems for precision farming show that their systems can be made interoperable using novel mechanisms for interfacing, such as linked data. In addition, new contacts can be made to explore new and emerging topics in the area of precision farming.

Collect new topics via the MKB stakeholders

As a result of ICT-AGRI, the Meta Knowledge Base is currently being a good instrument to link and connect important stakeholders in the area of ICT and agriculture. This instrument can also be used to collect the current status and potential gaps in a certain subdomain of agriculture, e.g. precision farming. In 2016, the MKB can be further used to organize a survey to collect a broad view on a map for the current use of standards for compatibility, both at connectivity as well as information level and the gaps in there. Based on this survey and its results, new specific topics for research and innovation in precision farming can be derived.

5.3. Instruments for investing

Beside the classic call instrument of ICT-AGRI ERA-NET, also other instruments exist for further stimulation of the research & innovation topics in ICT in agriculture and more specifically in precision farming.

Knowledge Hub

In order to align national research programming, new ways of working together are required. A new and innovative instrument that enables this is the“Knowledge Hub”. A Knowledge Hub associates 3 complementary dimensions: Research, Networking and Capacity Building. A Knowledge Hub functions through a two-step process in which researchers submit a Letter of Intent (LoI) to their national funder who then decides eligibility on a competitive or non-competitive basis, according to the countries’own rules. Eligible groups are then invited to submit a full proposal as one single consortium, which is then reviewed by an international evaluation committee. Countries may choose to fund new research or to participate only through the funding of coordination costs, which cover networking, additional costs for coordinating and costs for running common activities initiated by the Knowledge Hub. Knowledge Hubs are particularly well suited to research areas with a relatively restricted research community. In addition, a knowledge hub can serve as a strong platform of users of PF systems that require interoperability and the use of standards for that purpose from the PF system suppliers.

Funding on top of H2020

The H2020 program focuses on various societal challenges and challenges towards leadership in industry. Among them is also societal challenge 2 on Food Security and Sustainable Agriculture and Forestry, among others. When looking at the specific topics that can be funded in that challenge, there is very few ICT-related work in. With respect to technology, the focus is more on specific technology to solve e.g. a certain production problem. At the moment, the EC is working on the definition of the Work Programme for 2016-2017. The main challenge and action in 2016 for the ICT-AGRI ERANET is to bring in as best as possible the research and innovation topics on precision farming (and others based on the SRA). Under the assumption that part of these topics will be adopted in the Work Programme, the next action is to investigate the possibilities for providing additional funding for projects on these topics that are accepted in H2020.