



1 Executive Summary

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 increased complexity of the systems inhibits easy adoption and makes calculations as to the financial benefits uncertain. These issues can be resolved by improving the decision making process through better *Management Information Systems*, improved data interchange standards and clear management methods.

The FutureFarm project's starting point has been the identification of the current and future data, information and knowledge management needs on the farms, as well as on the way that these needs will evolve in the future and that will influence farm data, farm information and farm knowledge management systems. Existing systems were categorized and evaluated through interviews with the project's pilot farms.

Farm Management Information System (FMIS) specification was produced, by using a user-centric approach. The system boundaries were identified as well as the farmer's personal management strategies. The integration in the FMIS of information coming from online soil sensors was used as an integration case study. The architecture of the proposed system is based on the Service Oriented Architecture. The main characteristic of such an architecture is that it allows to different publishers to develop components of the FMIS which can then be integrated to it with the use of a common vocabulary. The concept of the assisting services for the future FMIS was defined. Actors and information flows, usage processes and data elements for the FMIS have been modelled and analysed, and functional requirements of FMIS have been determined. The outlined system elements and requirements are very complex and diverse depending on the farm production type, level of automation and inherent business processes. When looking to the future, external services as decision making assisting features will become an important part of FMIS concept. At the moment, the utilisation of scientific models together with the large amounts of data in different formats produced by modern farm machinery, sensors located within the farm, remote sensing, etc. is still an open area of research and new methods are developed continuously. The seamless incorporation of new functionality and assisting features into an existing FMIS is of paramount importance.

An analysis of selected agricultural standards resulted in a methodology on how (and under which conditions) these standards could be stored in a machine readable format. Then, the software architecture as well as a prototype system for automated agricultural standards retrieval (and evaluation) was produced. Although specific problems still need to be solved, whether this system will be utilized or not is mainly a political question.

Further investigation is required in order to find out how automated retrieval of agricultural rules and standards can be adopted by the agricultural sector in Europe. Also, developing autonomous and visual crop detection and crop modeling in order to model nitrogen response and weed development in combination with the water response functions is now required in order to prove the advantages of the use of precision farming technologies. The use of semantics is inevitable for an open service oriented FMIS, but therefore the development of a common ontology language for the agricultural sector in Europe is required.

Precision farming was seen within the project as a technology that demands the development of information systems in agriculture. Therefore, the strategies in which farmers communicate and cooperate in the adoption of precision agriculture were identified as well as the precision farming potential of the EU areas. The most prominent precision farming technology to be used in the near future was found to be control traffic farming on the basis of its economic returns. The highest precision farming adoption potential have areas on the central parts of Western Europe.

The specifications of a farm's portal from the external stakeholders point of view, revealed that the history of the farm, information about the producers in the form of curriculum vitae, farm location, climatic and soil conditions and, last but not least, farming practices, is the information that the consumers would like to see in it. Farmers would also like to be able to market other farm services through the portal, in the case of a multifunctional farm.



The consortium believes that further ICT developments in agriculture will include the development of agricultural robotics in collaboration with advanced FMIS systems.



2 Summary description of project context and objectives

FutureFarm project basic idea

Developing codes of good farming practice, diversifying markets and production systems as well as European standards of sustainable agricultural production systems require implementation of more elaborate management strategies. These have to respect specific ecological conditions, demands from the rural regions and those from the value-added chains. On top of that, these strategies have to be simple, but flexible enough to be adapted easily to changing economic or environmental conditions and they need proof of their compliance. Beyond that, the demand for information about the production processes is growing, both from the perspective of the value-added chains (traceability) as well as from regional stakeholders in order to fulfil multifunctional objectives by farming. An important prerequisite for farmers to comply with all these different demands is to easily have sufficient and timely information available for decision making or providing documentary evidence. The rapid development of technologies for information and communication, new sensors as well as the vast potentials for providing geo-referenced data (remote-sensing, on-line sensors, public databases etc.) also allows farmers to access new and high quality data and use them as specific information in decision making or process documentation. With automated data acquisition and handling in an on-farm management information system the farmers can be seen to comply with a rapidly growing demand of standards in the management of the production processes.

Precision Farming (PF) in Europe uses new technologies in information handling and management as well as in managing the spatial and temporal variability found on all farms. Such explicit information use improves economic returns and reduces environmental impact. Precision farming is very data intensive and historically linked with site specific activities and management on the field. It has become very clear in recent years that PF is not limited to site-specific farming. The use of techniques and methods that form precision farming can provide a wealth of information and tools to handle and apply information properly for any type of farm in any region. This information-driven approach can be used to help improve crop management strategies and proof of compliance through documentation.

The introduction of advanced ICT technologies into agriculture will also be a significant progress in all efforts for measurements oriented payments within agro-environmental programs and related efforts to enforce environmentally sound systems in land use within the EU. This also includes the Best Management Practice according to the cross compliance scheme.

Crop products going into the food chain must show their certified provenance through a recognised management strategy and subsidy payments to farmers are now linked to respect of the environment through compliance to standards. To this end, an integration of information systems is needed to advise managers of formal advice, recommended guidelines and implications resulting from different scenarios at the point of decision making during the crop cycle. This can be achieved by integrating real-time modelling (a crop growth and development model linked to sensors within the growing canopy), with expert systems that have been configured with the guidelines from a recommended management strategy (e.g. organic, ICM, IPM, factored risk etc) as well as legal guidance (such as health and safety and environmental protection). This will directly help the farm or crop manager to make better decisions. Expert knowledge in the form of models and expert systems can be published and made available in a machine readable form on the internet or made available as web-services to be dynamically bound into the end-user software. As the relevant farm data is already in the proposed information system, or may be automatically integrated using standardised services, documentation in the form of instructions to operators, certification of crop province and cross compliance of adopted standards can be generated more easily than with current systems.

Crop products can also stay on the farm – besides traditionally fodder this will be in the future the internal use of biofuels or bio energy. That would boost the possibility of moving towards a highly energy-efficient or even energy-neutral farm. This is supported by the significant reduction of energy required by small smart machines that can work by themselves while intelligently targeting inputs.



The FutureFarm project attempted to address the balance of technological opportunities combined with environmental and socioeconomic needs with the key role of information management. Intensive use of information and knowledge will be a substantial activity of all commercial EU farms in future.

General aims

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 increased complexity of the systems inhibits easy adoption and makes calculations as to the financial benefits uncertain. These issues can be resolved by improving the decision making process through better *Management Information Systems*, improved data interchange standards and clear management methods.

Therefore the collaborative project FutureFarm defined the following objectives as relevant and worked on delivering them:

Objective 1

Develop a vision of the farm of tomorrow from the perspective of the project team and invited stakeholders to show a better understanding of how farming will develop. This will include identifying relevant drivers and their potential impact on crucial processes in knowledge management in arable crop production.

Call objectives met: *Vision of new knowledge based biological, technical, social and economic innovations.*

Objective 2

Identify and analyse a range of formal and informal management strategies in crop production and identify required indices in terms of management and practices that would constitute compliance to standards within the strategy.

Call objectives met: *Cost efficient compliance with standards as an integral part of farm operations.*

Objective 3

Analyse and specify the required knowledge, information and methods needed to adopt specific management strategies. Produce a set of specifications that can be used to define a flexible and dynamic Farm Management Information System (FMIS).

Call Objectives met: *Special requirements for high value markets, sharing good farming practices, recognition and communication of ecological and cultural diversity as well as regional demands on multifunctional production of non-commodities.*

Objective 4

Apply and test the general principles of a FMIS by developing a prototype of an integrated a FMIS. This will include elements from different methods and sources (e.g. GIS, DSS, expert systems, trusted third party knowledge, formal and informal knowledge transfer etc.). Ease of use and largely automated data handling procedures will be an important aspect. Working prototype will be made available for evaluation.

Call objectives met: *Integrated technologies and ICT tools to make cost efficient compliance with standards an integral part of farm operations.*

Objective 5

Provide a socio-economic, environmental and technology assessment to understand the drivers and issues from Objectives 1, 2, 3 and 4. Recommendations will be expected to show how development can be made to take advantage of opportunities and avoid obvious problems.

Call objectives met: *Understanding of overall trends of European societies, new models of relationships with consumers and citizens, rural economy, the multifunctional European farming model delivering public goods.*



Objective 6

Assess the influences of robotics and biofuels on economic and energetic efficiencies of farm production. Existing robotic and closed-loop on-farm biofuel systems will be demonstrated and evaluated as examples of internal flow management.

Call objectives met: *New models of material flow management, based on information and knowledge management supporting on-farm or local integration of environmentally friendly closed loop processing facilities, energy efficient cultivation with light machinery, precision farming and robotics.*

Objective 7

Develop a typology for information technologies in European farming (like precision farming) and a typology on its suitability for different farm groups within the member states of the EU. Application, integration, demonstration, generalisation and dissemination of project results on commercial farms within EU-countries.

Call objectives met: *Generalisation of project results and demonstration of all of the above points and showing its feasibility for many future farms in the EU.*



3 Description of the main S&T results/foregrounds

3.1 Introduction

The scientific results of the Futurefarm project are grouped into four main categories, depicted in the chapter structure followed for this report. The specification of a Farm Management Information System started from seeing the farm as a system (not necessarily a software or technological system) and the farmer as the primary decision maker. The Soft Systems Methodology approach was used to analyse both the farm but also the farmer's decision making procedures. The second chapter is more oriented in the Farm Management Information System, narrowing down the analysis conducted in the previous chapter to the information system level. The specification of the system architecture is presented but also the farmers' personal management strategies are analysed with the ultimate aim to be incorporated in the FMIS. The concept of assisting services is also introduced in this chapter, in order to describe a system of systems (the FMIS), that will be able to interface with various other subsystems in order to acquire and supply information. The third chapter is focused on selected assisting services of the FMIS. The online soil sensing paradigm is selected as a case study. Nevertheless, the issue of automated compliance checking and the structure of the relevant assisting services cover the biggest part of this chapter. This depicts also the special focus given by the project partners on this issue. Finally, the last chapter presents different socioeconomics aspects of the information systems as they are now in agriculture, as well as of existing precision farming technologies.

3.2 A Farm Management Information System specification: The farm seen as a system

The agricultural production sector faces increased pressure in terms of reduced margins of earnings. Farmers are constantly required to reduce production cost, maximise their physical output while maintaining the highest product quality. These requirements go hand in hand with adherence to strict environmental, social, health, and safety regulations (e.g., certification schemes such as International Food Standard (IFS) and GLOBALGAP, Albersmeier *et al.*, 2009). The use of information and communication technology (ICT) and farm management information systems (FMIS) and decision support has shown great promise for achieving the above goals, especially in the context of precision agriculture. Murakami *et al.* (2007) found that the most important requirements for a Farm Management Information System (FMIS) include: a) a design aimed at the specific needs of the farmers, b) a simple user-interface, c) automated and simple-to-use methods for data processing, d) a user controlled interface allowing access to processing and analysis functions, e) integration of expert knowledge and user preferences, f) improved integration of standardized computer systems, g) enhanced integration and interoperability, h) scalability, i) interchange-ability between applications, and k) low cost. A dedicated design of a FMIS complying with the above requirements involves an identification and specification of the scope and boundaries, an identification of system components (actors, decision processes, etc.) combined with information modelling, and finally, as part of the overall knowledge management, an identification of knowledge content in decision processes and functional requirements.

An outline of the essential entities and boundaries of a dedicated FMIS were defined by Sørensen *et al.* (2010a). The boundaries and scope of the system were analysed and described in terms of actors (entities interfacing with the system such as managers, software, and databases) and functionalities. The soft systems methodology (SSM) (Checkland and Scholes, 1999) was used for the development of a conceptual model for an effective FMIS based on information derived from pilot farms representing diverse conditions across the EU. The conceptual model was divided into four sections: internal data collection, external information collection, plan generation and report generation. The data collection and processing is an automated monitoring system, whereas the report and plan subsystems are to be initiated by the farm manager. The external repository contains information on standards, rules, all types of guidelines for farm activities etc., made available for the FMIS. This conceptual model is the first step towards the actual design of a novel FMIS.

The second step of the specification of the FMIS concerned the material and information flows (Sørensen *et al.*, 2010b). More specifically, the information flows and relevant input data were given for the strategic, tactical, and operational planning levels for field operations, together with the execution and evaluation phases. The information flow definitions included the actors and decision processes involved in the overall operation, and specified which



information must be encoded in the system, provided by partner/actors, and produced by the system. A user-centric approach to model the information flows for targeted field operations was used. From the six field operations (tillage, seeding, fertilizing, spraying, irrigation, harvesting) analysed in the FutureFarm¹ project, the information model for the fertilisation case was selected for analysis. By specifying in detail the information provided and the information required for the information handling processes, the design and specification of the information flows was derived. This involved explicitly specifying tacit knowledge of the farmer as a way to extend the FMIS design into automated decision-making. Core-task analysis and core-task demands were utilized as premises for the modelling of information flow from the farmers' point of view (Norros, 2004). The information models were centred on the farmer as the principal decision maker and involved external entities as well as mobile unit entities as the main information producers.

The next step following the conceptual modelling and the information modelling involved the specification of the knowledge content of the decision processes and the involved data imbedded in the information entities. This finalizing step in the design process together with the derivation of the functional requirements are further intended to support and guide the selection of the technological infrastructure of the FMIS.

During the course of the FutureFarm project, actors and information flows (deliverable 3.2, Sørensen *et al.* 2009), usage processes and data elements (deliverable 3.4, Sørensen *et al.* 2010) have been modelled and analysed, and functional requirements of FMIS have been determined (deliverable 3.5, Pesonen *et al.* 2010). The outlined system elements and requirements are very complex and diverse depending on the farm production type, level of automation and inherent business processes. When looking to the future, external services as decision making assisting features will become an important part of FMIS concept. At the moment, the utilisation of scientific models together with the large amounts of data in different formats produced by modern farm machinery, sensors located within the farm, remote sensing, etc. is still an open area of research and new methods are developed continuously. The seamless incorporation of new functionality and assisting features into an existing FMIS is of paramount importance.

3.2.1 System analysis and conceptual model

Future and even current European farmers are experiencing that the managerial tasks for arable farming are shifting to a new paradigm, requiring increased attention to economic viability and the interaction with the surroundings. To this end, an integration of information systems is needed to advise managers of formal instructions, recommended guidelines and documentation requirements for various decision making processes. In the EU funded project FutureFarm, a new model and prototype of a new Farm Information Management System (FMIS) which meets these changing requirements has been developed.

The boundaries and scope of the system are described in terms of actors and functionalities, where actors are entities interfacing with the system (e.g. managers, software, databases). In order to analyse the complex and soft systems situations of how to develop an effective FMIS, which effectively meets farmers' changing needs a conceptual model was developed based on soft systems methodology (SSM) and based on information derived from four pilot farms representing diverse conditions across the EU that are partners of the FutureFarm project. The system components were depicted as part of rich pictures and linked to the subsequent derived conceptual model of the overall system as an outline for the development of the specific FMIS requirements. This research has shown the benefit of using dedicated system analysis methodologies as a preliminary step to the actual design of a novel farm management information system compared with other more rigid and activity oriented system analysis methods.

The conceptual model for the FMIS derived from SSM analysis is presented in Figure 1 using UML notation. The model divides the FMIS into four functional components: internal data collection, external information collection, plan generation and report generation. The data collection and processing is an automated monitoring system, whereas the report and plan subsystems are to be initiated by the farm manager. From this component-based model of the required system, the formal specification of the behavior and interfaces of each component, based on the dependencies illustrated in Figure 1 (dashed arrows), may be straightforwardly derived and used as the basis for implementations.

To summarize, system analysis as a preliminary step to the actual design of a novel FMIS has identified the internal as well as external conflicts and problems that the farm manager currently faces. The novel conceptual design of FMIS has shown the possibility of clearly capturing the functional elements that support real-time management decisions and support reporting as well as application generation and improvement of the monitoring of compliance to management standards.

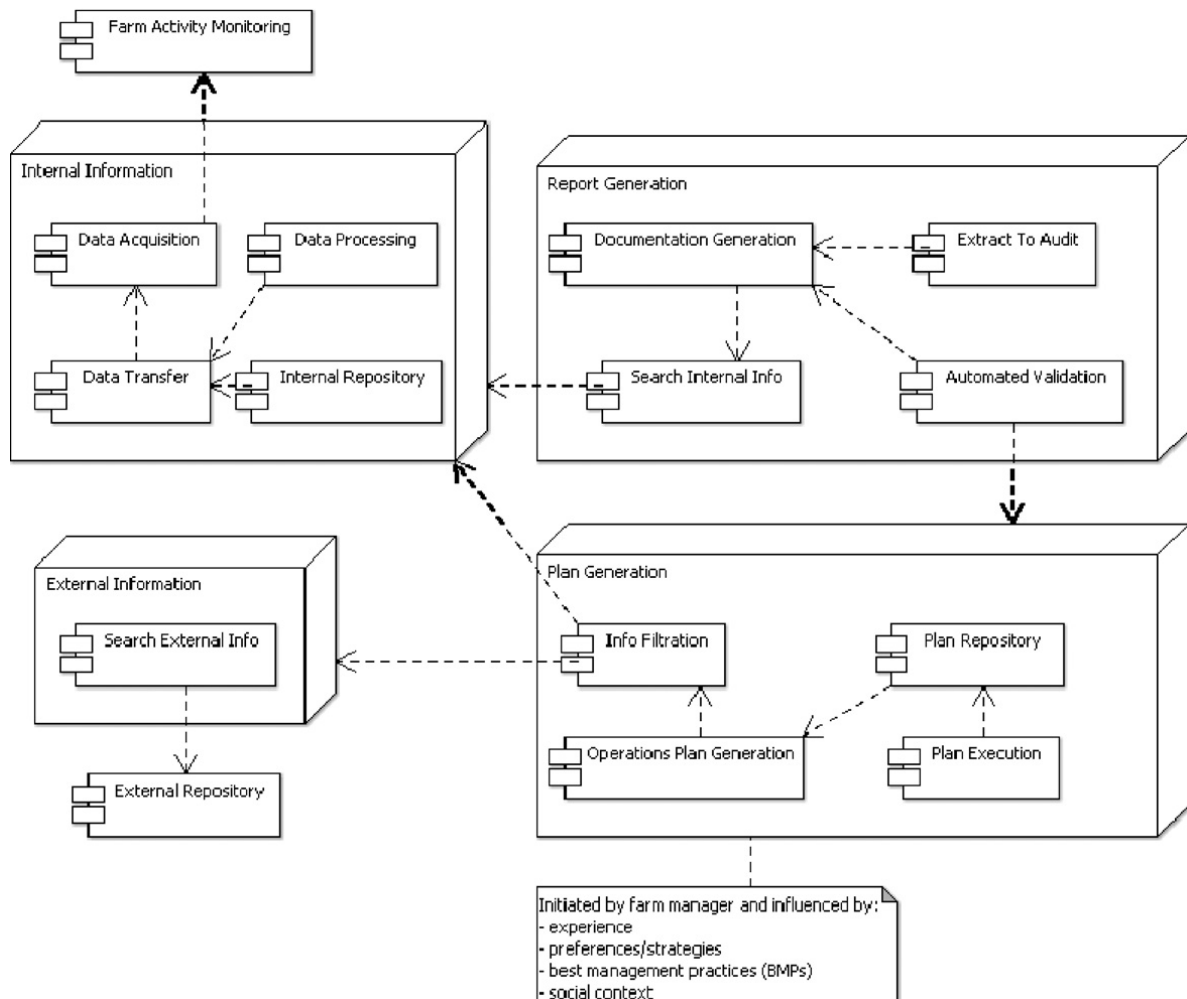


Figure 1: The concept of the FMIS

3.2.2 Specification of material and information flow: The farmer as a principal decision maker

Agriculture and farmers face a great challenge in effectively manage information both internally and externally in order to improve the economic and operational efficiency of operations, reduce environmental impact and comply with various documentation requirements. As a part of meeting this challenge, the flow of information between decisions processes defined as realizing a decision must be analyzed and modelled as a prerequisite for the subsequent design, construction and implementation of information systems, like the proposed novel FMIS.

The actors, their role and communication specifics associated with the various decision and control processes in farmers' information management were identified. Core-task analysis and core task demands from earlier research are utilised as premises for the modelling of information flow from the farmers' point of view. A user-friendly generic FMIS design reference model has been the primary objective for the study in which planning, execution and evaluation measures have been incorporated. A user-centric approach to model the information flows for targeted field operations has been adopted and presented. The information models are centred on the farmer as the principal decision maker and involves external entities as well as mobile unit entities as the main information



producers. This is a detailed approach to information modelling that will enable the generation of a Farm Management Information System in crop production.

Table 1 gives an overview of the different planning levels together with the main parts of the information flows required by the decision processes or produced by the decision processes. By specifying in detail the information provided and the information required for the information handling processes, the design and functionalities of the individual information system elements can be derived. Much of the information flows exists as tacit knowledge of the farmer, but in order to specify the elements of a information system which extend into for automated decision making, it is necessary to explicitly specify the detailed information flows for individual planning tasks.

Table 1: Planning levels and indicative information flows

Planning level	Information required	Information provided
Strategic planning or design of the production system: Design of production system for a period of 1-5 years or 2 or more cropping cycles – specifically the labour/machinery system and selection of types of crops	<ul style="list-style-type: none"> • possible production levels and price developments • operations demands • possible work methods • available machinery on the market • costs 	<ul style="list-style-type: none"> • number and dimensions of machines • machine capacity • labour requirement • crops selected
Tactical planning: Setting up a production plan for a period of 1-2 years or 1-2 cropping cycles.	<ul style="list-style-type: none"> • strategic plan • availability of land, buildings and equipment • external/internal standards 	<ul style="list-style-type: none"> • crop plan • machinery replacement • fertiliser/chemical application plans • maintenance plans • labour budget (peak loads)
Operational planning: Determining activities in the coming cropping cycle, i.e. within the coming season	<ul style="list-style-type: none"> • tactical production plan • internal/external standards • maintenance plan for land, buildings and equipment 	<ul style="list-style-type: none"> • required/ optional operations • operations urgency • operations specifications
- scheduling: Work scheduling setting up formulations of jobs. Planning the implementation of work in the short term.	<ul style="list-style-type: none"> • required operations • urgency of operations • soil and crop status • weather forecast • workability criteria • availability of labour and equipment • operations specifications 	<ul style="list-style-type: none"> • work plan for planned operations indicating: <ul style="list-style-type: none"> - starting time - duration - work-sets required
Task formulation: Handling tasks concerning inspection of formulated tasks	<ul style="list-style-type: none"> • equipment breakdowns • unavailable material • change in soil, crop or weather conditions • priority changes 	<ul style="list-style-type: none"> • deviation from plans/schedules
Execution: Controlling tasks, and work-sets performance – task control and operation control	<ul style="list-style-type: none"> • work time elements (effective time, ancillary time, preparation time, disturbance time etc.) on work-sets • operations specifications 	<ul style="list-style-type: none"> • realised work time • realised capacity • set points for implement



Evaluation: Comparing planned and actual executed tasks

- *realised work time*
 - *realised capacity*
 - *realised yield*
 - *documentation information*
 - *deviations from planned tasks*
-

In order to summarize, the user-centric information flow models propose the implementation of effective managerial functions to the FMIS, but at the same time, they expect the farmers to be ready to adopt new working habits and perhaps also undergo further training. Also, farmers will be able to gain increased insight into their production processes and would be able to evaluate the performance of the chosen technology. This will lead to better process control as well as an improved capability of documenting the quality of farming e.g. traceability, to markets and administration.

3.2.3 Knowledge and information to be encoded

Selected parts of the fertilisation information flow model were encoded, in particular those parts that are directly relevant to assessing compliance to farm management and crop production standards. The encoding forms a core of the new information and knowledge management system structure, and the fertilisation information flow is presented as one use-case of how the proposed system should be implemented and to illustrate the process, which should be followed in identifying the requirements for all knowledge encoding for all farm operations.

The encoding concerns strategic and tactical planning as well as support in the execution phase of the fertilising task. Different information systems are expected to be integrated to serve the farmer and to provide automatic assistance and support. The specific parts of the fertilising information flow to be encoded include: arable farming strategy, relevant private (industrial and commercial) standards for the fertilizing, relevant legislative standards, fertilising frame service, assisting information, documentation requirements, limits and restrictions on fertilizer use, information acquisition service, assisting information about fertilising rules, updated fertilising information, expected crop cycle, fertilising history, selected fertilizing technology, and formulated TASK file.

To summarize, critical parts of the information management in farms having a significant (and even fatal if errors are made) impact on the overall outcome of the farming activities have been encoded. The encoded system part is generic in its functionality and can serve as an example case that can be applied also to other parts of the information system described flow models.

3.2.4 Information models specifying usage processes and data elements

Information flow models depict the information usage processes, so called decision processes, information inputs needed and also the actors responsible for delivering or using the information. The content of each usage process and information input can be described accurately, either in a way the reality is at the moment or in a way we wish the reality to be in the future. Each actor can determine the needs and requirements set to them and act accordingly.

The content of the “Process” boxes of the information flow model, which represent the usage processes of the information and on the “Information” boxes, which represent the data elements, has been identified. This was done for the identified planning levels (Strategic, Tactical, Operational, Scheduling, Task formulation, Execution, Evaluation) and for selected field operations, i.e. tillage, seeding, fertilizing, spraying, irrigation, harvesting. The description of the data content in the fertilizing case has involved quality and quantity, spatial aspect and rules, etc. As an example of the information flows produced, Figure 3 presents the identified actors for the information modelling and Figure 2 presents the information modelling for the fertilizing case at the operational level.

For the fertilizing case, the detailed data elements and the usage processes were identified, so as to be incorporated in the implementation of the prototype FMIS.

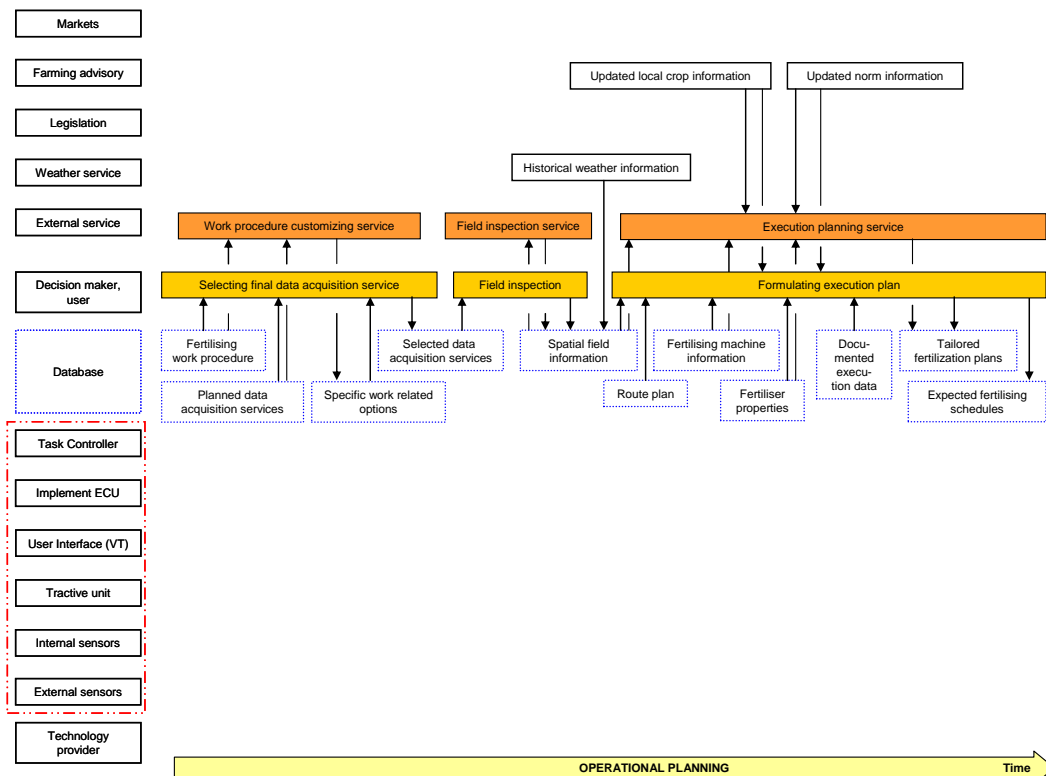


Figure 3: Fertilizing operation: Operational planning focusing on the final formulation of the execution plan: decision processes, information inputs needed and the actors responsible for delivering or using the information.

To summarize, the identification of the usage processes as well as the data elements have shown the complexity of the decision making process within the agricultural domain. In fully structured and formalised information flow decomposition, many actors are required to deliver information to the decision processes in order to fully emulate the tacit knowledge that farmers and decision makers are currently using. Especially, the concept of assisting services was further evolved in order to sustain the need of more automated decision processes.

3.2.5 Functional requirements of the derived information system

The various functional features required from FMIS were derived based on the user-centric information modelling by Sorensen et al. (2010b). Specifically, there have been derived the functional requirements for the services involved in the fertilisation case, and in a similar manner, functional requirements can be derived for the services participating in the remaining tasks in arable farming (tillage, seeding, spraying, irrigation and harvesting). The Decision Maker (farmer) has complex communication and data exchange between his/her own data storage and external actors. The decision processes need the information input in a certain order. The required speed in data exchange increases when decision making timespan decreases e.g. when shifting from operational planning to execution. The quality of the needed data depends on the demands of the decision process where it is used. The information used in operational, execution and evaluation level is spatial, and thus information management requires spatial data handling, analysing and presentation features.

To summarize, the various components – services of the FMIS and their functionalities can be derived based on specifications of the user-centric information modelling of the agricultural tasks in arable farming. The basic functional requirements include simple user-interface, automated and simple-to-use methods for data processing, complete user control, integrated rule-based knowledge, adaptable to local conditions, seamless integration and

Figure 2: Identification of actors as part of the information modelling

interoperability with other software packages, using open data standards, interfaces, and protocols, scalability, data interchange using meta-data, and low cost implementations.



3.2.6 Requirements Analysis for a farm portal: The external stakeholders point of view

The farm portal in the project was seen as a separate future system that will facilitate the communication of the farm with the outside world. Although the FMIS analysis was based on the farmer as the primary decision maker and user, here the requirements analysis involved the identification of all the relevant stakeholders and their involvement in the requirements definition. The envisioned farm portal is expected to derive information from the FMIS in ways that are presented later in this report. Nevertheless, in the requirements analysis it is dealt with as a separate system.

The definition of such a Farm Portal was set to be a marketing and communication centre for farmers and their chain partners and in parallel a trust centre for traceability purposes.

The requirements for the generation of a **Farm Portal** were identified stating both a theoretical analysis and a field survey with interviews with potential stakeholders in three countries (Denmark, Germany, Greece).

The field survey with personal interviews showed that the consumers would demand from a farm portal to present the history of the farm, information about the producers in the form of curriculum vitae, farm location, climatic and soil conditions and farming practices. If field experiments are carried out in the farm then the place and size of experimental fields and with which research institute or university is collaborating with. Regarding information about the products that are produced in the farm, the most important are the main standards, regulations and practices (animal welfare, antibiotics), followed by the production processes for the crops and the animals. It is very important to have a link to other portals that can help people to understand more about EU standards like Cross Compliance, Common Agricultural Policy, and Practices that are referred to Natural Conservation. On-line weather of the place of farm is also useful information of this portal. Surveyed consumers would like to have the opportunity to buy agricultural products directly from the farm. To improve food quality, it is very important to have a space where everybody can comment if there are any complaints or useful comments.

From the surveyed farmers' point of view, it is important to have a webpage where the farmer will refer about the opportunities for accommodation and visiting the farm for different activities such as riding or upcoming events on-farm or in the surroundings. Not many farmers requested forums or blogs. Regarding performance requirements, the portal and all associated application systems must be designed to allow continuous operation and must be capable of maintaining the integrity of all the data, which it controls and makes available to other people. The capacity of the server that is going to host the portal must be quite big, because of the necessity of at least two languages.

Issues regarding the communication of the farmers with advisors and research institutes were also brought up by the surveyed farmers. Although in the FMIS specified architecture, this communication would not necessarily happen through the farm portal, farmers' recommendations are still to be taken into account. Surveyed farmers would accept the online data exchange with advisors and research centres as long as the security and protection of the data is guaranteed.

3.3 The Farm Management Information System

Management information systems (MIS) is an integral part of the overall management system in an purposeful organisation comprising tools like enterprise resource planning (ERP), overall information systems (IS), etc. ERP is an industry notion for a wide set of management activities which support all essential business processes within the enterprise. As a part of the ERP, the **information system** (IS) refers to data records and activities that process the data and information in an organization, and it includes the organization's manual and automated processes supporting the business processes. Information systems are the software and hardware systems that support data-intensive applications. Especially, information systems provide the possibility to obtain more information in "real-time" enabling a close monitoring of the operations performance and enhance the connection between executed operations and the strategic targets of the enterprise.

Management Information Systems differ from regular information systems because the primary objectives of these systems are to analyse other systems dealing with the operational activities in the organization. In this way,



MIS is a subset of the overall planning and control activities covering the application of humans, technologies, and procedures of the organisation. Within the field of scientific management, MIS is most often tailored to the automation or support of human decision making. In this way was also seen the Farm Management Information System within Futurefarm.

In this chapter, the conceptual model of a Farm Management Information System is presented, as well as the specification of the system architecture. Due to the complexity of the information needed as well as the variety of the sources from which this information needs to be retrieved, the concept of assisting services is also introduced. The Farm Management Information System is mainly seen as a system of systems. Therefore, its boundaries are only vague defined, since they will depend on the specific implementation each time. Furthermore, the way that the farmer’s personal management strategies could be embedded in such a system is analysed.

Specific implementations of assisting services are presented in the following chapter.

3.3.1 Conceptual Model of a Farm Management Information System (FMIS) and the assisting services

Increased amount of needed and used information in precision agriculture and increasing use of automation in farm machinery force farmers to utilise external services to support the decision making as well as to use machine readable communication between FMIS and other actors, especially the machinery – see Figure 4 . Table 2 presents typical assisting services of the FMIS needed to support farmer’s decision making.

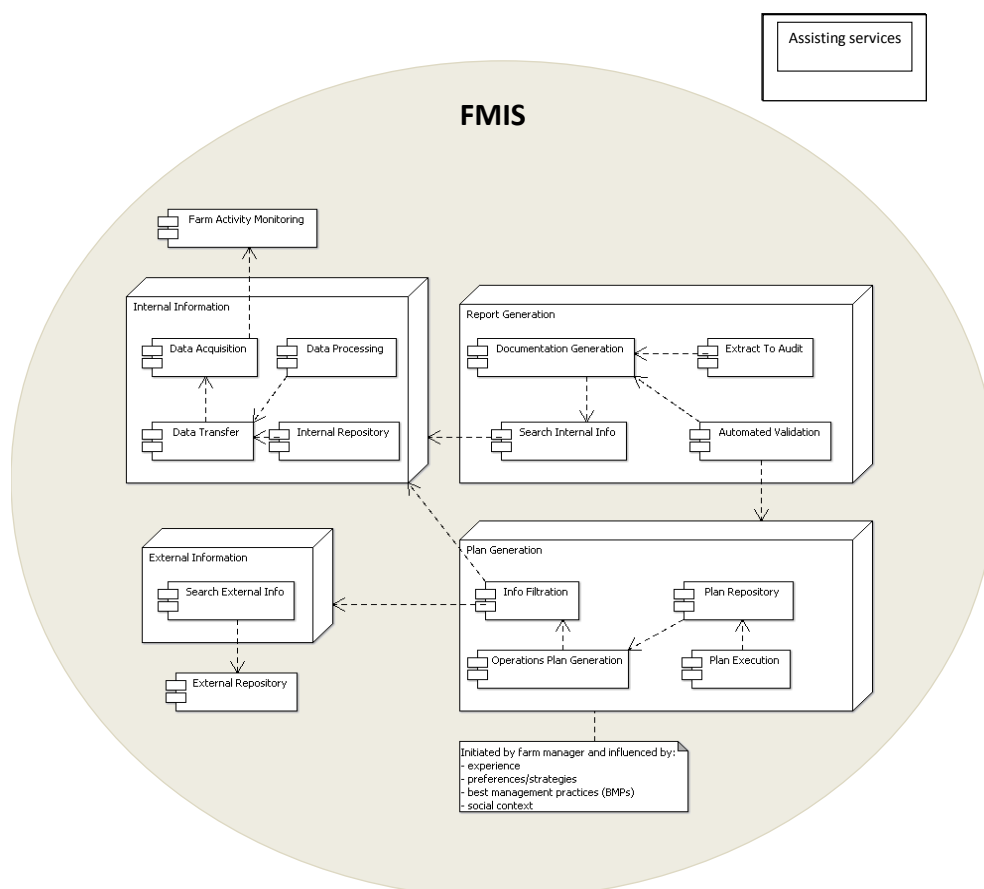


Figure 4: Conceptual model of the FMIS and the assisting services



Table 2: Typical assisting services of FMIS to support the farmer's decision making

<i>Assisting FMIS feature</i>	<i>Functionality of the feature</i>
Fertilizing frame service	<p>Receives information from:</p> <ul style="list-style-type: none"> - Markets; Relevant private standards for the fertilizing, - Farming advisory; Relevant management practices, - Legislation; Relevant legislative standards - Farm DB; Arable farming strategy, Soil classification, Fertilising and yield history - Technology provider; New type of fertilizers <p>Sends Documentation requirements and Assisting information for Formulating the fertilizing strategy</p>
Economical service	<p>Receives information from:</p> <ul style="list-style-type: none"> - Markets; Present input prices and expected products prices - Farming advisory; Relevant Farming economical information; example budget calculations etc. - Farm DB; Arable Farm economic information - Technology provider; Available technology and costs <p>Sends Assisting information for Formulating the fertilizing strategy</p>
Technology assessment service	<p>Receives information from:</p> <ul style="list-style-type: none"> - Farm DB; Requirements for affordable technology, Field location <p>Sends Assisting information for Selecting fertilising features</p>
Feature assessment service	<p>Receives information from:</p> <ul style="list-style-type: none"> - Farm DB; Selected fertilizing technology - Technology provider; New technical information <p>Sends Updated technical information and machinery selection for Choosing fertilising technology: information and machinery</p>
Information acquisition service	<p>Receives information from:</p> <ul style="list-style-type: none"> - Markets; List of available fertilizers, Available data acquisition services - Farming advisory; Recommended fertiliser use - Legislation; Limits and restrictions on fertiliser use - Farm DB; Expected crop cycle, Fertilising history, Selected fertilizing technology, <p>Sends Assisting information about fertilising rules for Acquiring planning information</p>
Farm and field customizing service	<p>Receives information from:</p> <ul style="list-style-type: none"> - Farm DB; Updated fertilising information, Field location, Fertilizers in storage <p>Sends Potential data acquisition services, Required fertilizer <ul style="list-style-type: none"> - types and rough amounts for Fertilising process planning</p>
Work procedure customizing service	<p>Receives information from:</p> <ul style="list-style-type: none"> - Farm DB; Fertilising work procedure, Potential data acquisition services, <p>Sends Specific work related options</p>



	<i>for Selecting final data acquisition service</i>
Field inspection service	<p>Receives information from:</p> <ul style="list-style-type: none"> - Farm DB; Spatial field information <p>Sends Spatial field information <i>for Formulating execution plan</i></p>
Execution planning service	<p>Receives information from:</p> <ul style="list-style-type: none"> - Farming advisory; Updated local crop information, Updated norm information - Farm DB; Spatial field information, Fertilising machine information, Fertiliser properties <p>Sends Tailored fertilization plans <i>for Selection of fertilising parameters</i></p>
Field observation service	<p>Receives information from:</p> <ul style="list-style-type: none"> - Weather service; Actual weather and forecast - Farm DB; Growing stage, soil and canopy moisture and weather conditions <p>Sends Growing stage, soil and canopy moisture and weather conditions <i>for Field observation</i></p>
Risk assessment service	<p>Receives information from:</p> <ul style="list-style-type: none"> - Farm DB; Actual and forecasted field conditions <p>Sends Analysed risks <i>for Schedule formulation</i></p>
Spatiotemporal soil and crop condition service	<p>Receives information from:</p> <p>Farm DB; Updated moisture conditions</p> <p>Sends Nowcast <i>for Selection of fertilising parameters</i></p>
Execution planning and validation service	<p>Receives information from:</p> <ul style="list-style-type: none"> - Markets; List of available fertilizers - Farming advisory; Recommended fertiliser use - Legislation; Limits and restrictions on fertiliser use - Farm DB; Final plan, Selected machine, Assisting information about fertilising rules, Fertiliser properties - Technology provider; Fertiliser properties <p>Sends Assisting information about fertilising rules, <i>for Updating execution plan</i></p> <p>Sends TASK file <i>for Intermediating Task Controller in machinery</i></p> <p>Sends Selected fertilizing schedule <i>for Inspecting and controlling fertilising task</i></p>
Spatiotemporal soil and crop condition service	<p>Receives information from:</p> <ul style="list-style-type: none"> - Weather service; Actual weather and forecast <p>Sends Nowcast <i>for Selection of fertilising parameters</i></p>
Assisting remote controlling service	<p>Receives information from:</p> <ul style="list-style-type: none"> - Farm DB; Operation status and documented execution data <p>Sends (Updated) Operation status and documented execution data</p>



	<i>for Inspecting and controlling fertilising task, Finishing or formulating execution plan</i>
Assisting (data processing) service	<p>Receives information from:</p> <ul style="list-style-type: none"> - Farm DB; Documented execution data, Documentation requirements <p>Sends Documented process data <i>for Compliance to standard check</i></p>
Assisting “Operational performance” service	<p>Receives information from:</p> <ul style="list-style-type: none"> - Markets; Present product price - Farm DB; Current fertilising performance, Target yield amount and quality + budget, Realised yield amount and quality <p>Sends Economical analysis of current technology</p>

3.3.2 Specification of system architecture

By inferring from the FMIS functionalities to the actual FMIS architecture, a network of distributed web services which offer the required functionality is a plausible solution. The implementation of these web services may vary and will depend on elaborated information flows. A major requirement will be that all services communicate via well defined and agreed upon vocabularies. In one case, the functional requirements could be addressed by standard (non SOA) software architectures; however the functionality range of these services (financial, agronomic, optimisation, modelling, etc) renders such an approach unlikely. A scenario where specialised services are implemented by companies competing against each other, by governmental or non-profit organisations will be more likely.

To summarize, there is a clear defined need to integrate emerging FMIS distributed web services with a well defined reference model depicting vocabularies. As part of a distributed architecture, an efficient data exchange is needed so that interpreters at various intersections can be avoided and it will be possible to have a cost-efficient implementation of the architecture.

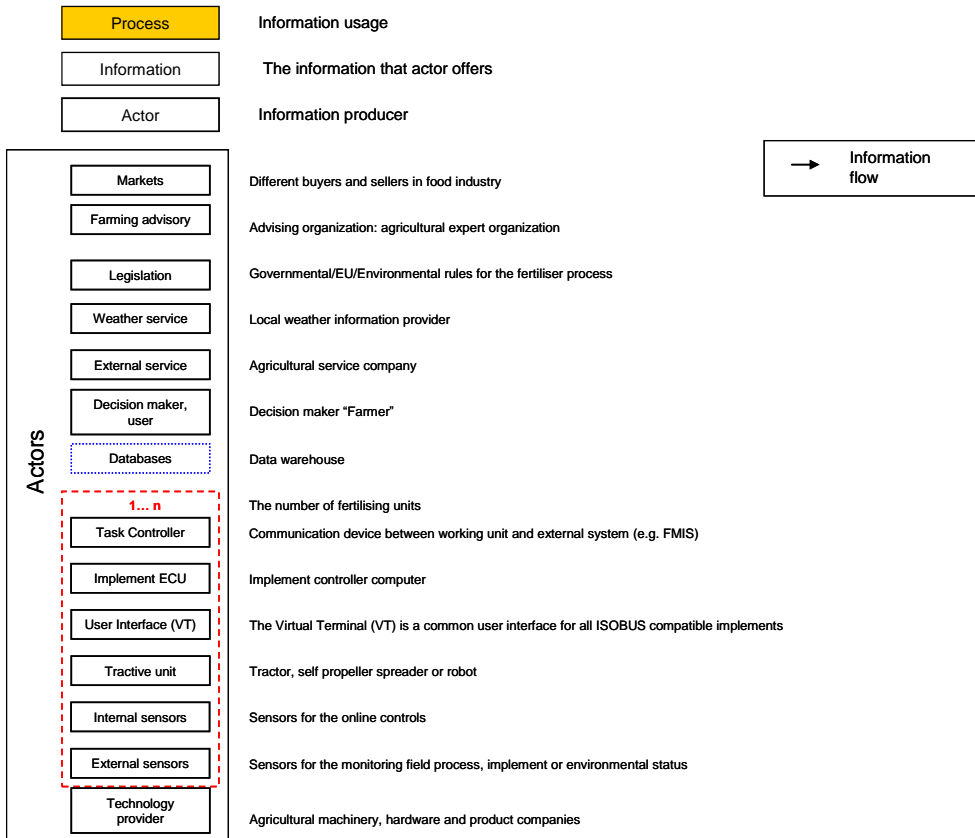
The developed FMIS of Future Farm is an application of applications (or a system of systems). The system architecture is case dependent, depending on the availability and knowledge of exploiting information produced by different applications. Each application consists of a stack of applications which act as services for other managing application, i.e. applications using other applications. Well defined data transfer interfaces make it possible to have a rich set of applications forming the actual core FMIS system and assisting external services. There is no precise definition of what application is in the FMIS and what can be an external service.

The overall FMIS is a collection of applications dependent on each other. The applications form a treelike hierarchical structure, where elements that are not dependent on other system components form the leaf elements of the trees. Applications that are used by other applications to produce their out-put are services for other applications and represented as node-elements. The application producing the out-put of the system is the root element in the tree structure. A single tree can act as a leaf for other applications. There can be numerous branches within a tree. A single branch can act as an independent application, or as a service for other applications dependent on it. A single branch can have multitude of child elements depending on the applications and interfaces provided.

As the Future Farm FMIS is a collection networked services, one specific architecture cannot be named. The structure of the system will be dependent of the use case and its several aspects as regard the information needs, available information sources, available relevant services, available interfaces between applications and services and the business models behind the applications, services and their interfaces. As each connection between different applications or services is an interface; open, harmonized and flexible interfaces are critical to provide. These interfaces enable a multitude of choices for different kind of system structures and business models of the proposed Future Farm FMIS.



The proposed Future Farm FMIS is an application of applications (or system of systems). The structure of FMIS is dependent on a specific the use case and involving a specific information need, a specific available information source, specific available relevant services, specific available interfaces between applications and services and the business models behind the applications, services and their interfaces.



3.3.3 Farmer's Personal Management Strategies and specification of their integration in a future Farm Management Information System

Within FutureFram, the FMIS is seen as a basic decision support tool for the farmer. Additionally, the specification of the system is centered on the farmer as the primary decision maker. Therefore, the personal management strategies of the farmers were analysed. The implementation of these strategies in a future FMIS could support the partial automation of the farmers' decision making. The implementation of these strategies within a prototype was not possible for the project, since there is a number of information still missing and a number of vocabularies still not defined.

Explicit personal management strategies were identified and analyzed in terms of the agricultural practice carried out; principal information needed; and decision objective and decision outcome. This was in line with the transformation of these narrative statements to be transformed into a FMIS. The personal management strategies that were identified for first time as a holistic approach were: maximised Yield; maximised return; minimised environmental impact; intercropping; replenishment; minimised risk of agronomic failure; minimised financial risk; minimised cost of production. To be consistent with the analysis for the compliance to standards, these personal strategies were also analysed for the same six field operations, namely tillage, seeding, fertilising, irrigation, spraying and harvesting. *Table 3* shows an overview of the analysis done.



Table 3: Farm management strategies, goals, methods and the various field operations

Formal Management Strategies	Farm Management Goals	Methods - Tools	Field Operations
Cross Compliance Organic Farming Integrated Crop Management Water Policy Market-based Farming Field Subsistence	Maximised yield Maximised Return Minimised Environmental Impact Input Replenishment Minimised Financial Risk Minimised Cost of Production	Conventional Practices Variable Rate Technology (VRT) Controlled Traffic Contour cultivation Intercropping Conservation tillage Robots Autoguidance Tracking – Tracing Selective Harvesting	Tillage Seeding Fertilising Irrigation Spraying Harvesting

The analysis resulted in the production of a UML model of these strategies.

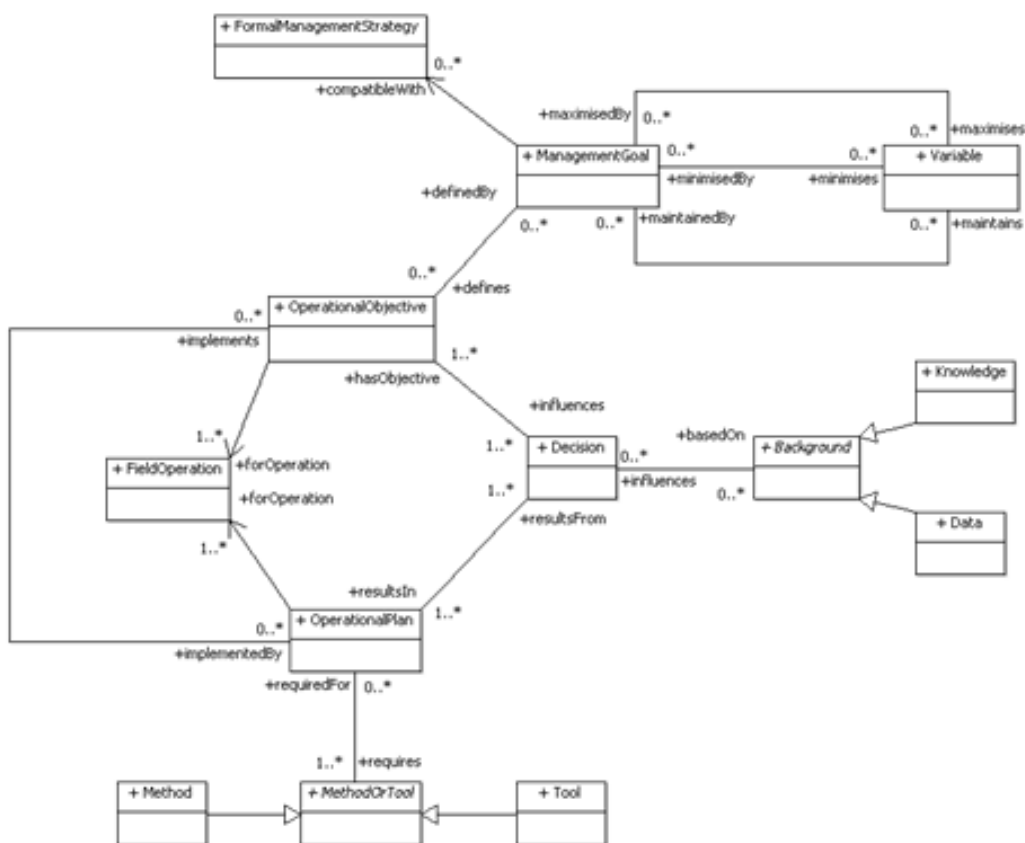


Figure 5: UML model of the farmer's personal management strategies.

Based on this model, a future Farm Management Information System will be able to support the farmer's decision making in a more automated way.



3.4 Assisting services within or outside the farm

The FMIS as defined earlier, is seen as a system of systems supporting farmer's decision making. The concept of assisting services has already been defined in the previous chapter. In this chapter, work done within the project in order to develop prototypes for selected assisting services is presented.

In order for the FMIS to evolve as a decision support tool, which utilizes a wealth of information to assist the farmer in his decision-making, the issue of integration needs to be addressed. Within the FutureFarm project, except of specifying the FMIS requirements and architecture, there has been an attempt to specify an architecture, which will allow the import of data acquired through precision farming recording technologies into the FMIS. Also, another architecture is defined to facilitate the automated exchange of agricultural regulations and standards.

3.4.1 On-line data acquisition and the FMIS

As a specific assisting service for the proposed FMIS architecture, the automatic import to the FMIS of data coming from online soil sensors was studied.

Whilst on-line instruments now exist to measure essential parameters on soil and crops, challenges remain in integrating these data into the FMIS in an efficient manner. These challenges stem from the fact that on-line collected data are with different formats e.g. images, spreadsheet xls, xlsx, proprietary binary, csv, etc.

Generally, on-line sensors consist of a sensing technology e.g. near infrared spectroscopy, a sensing unit e.g. optical probe or load cell, a digital global positioning system (DGPS) to record position, a software and laptop to record and store data in different formats. These are collected on a user specific designed platform, which is in most cases linked to the three point linkage of a tractor to record data on soil, crop cover, crop disease, weed intensity, etc. However, on-line sensors can also be linked or installed on commercial agricultural machinery such as yield sensors on combine harvesters.

Current data communication standard for tractors and machinery in agriculture is ISO 11783, which is rather well established and has gained market acceptance. However, there is a significant number of non-ISO-11783-compliant on-line sensors in practice. With the ISO 11783 standard, data on parameters related to tractor and machine performance, e.g. speed, draught, moment, etc. are managed, whereas different formats of data collected with non-ISO 11783 sensors are discussed.

With the former case, process data from sensors with CAN interface is converted into ISO 11783 XML and then imported into relational database at FMIS using RelaXML tool. There is also the export function database to task controller (TC) to provide task management as described in ISO 11783:10. In the latter case, the import service is based on local or public sharing or semantic mapping outputting AgroXML format for FMIS. Import is best performed as close to the generation of sensor data as possible to maximise the availability of metadata. Summarizing the recommendations of this case study:

1. Where possible, any producer of a third party file should be upgraded to include agroXML output.
2. A second choice is to provide a format exporter, which is incorporated in the workflow to be used by the original operator –integrated with the end of day or data transfer process.
3. A next choice is to include the function as an import filter at the time data is taken into a farm-office system.
4. Last choice is that the data is encapsulated in a raw format and incorporated later.

Automated unification will take place through a common data dictionary (semantics), an ontology based approach. It should also be possible to provide each translator with a manual interface to allow definition of the semantic mapping for the first import between systems. This mapping should be storable in the destination device to allow future translations to be entirely automated. The experience of other industries suggests such mappings can be productively shared in a community. As currently found in the industry, it is suggested that import processes are likely to remain to some extent manufacturer specific or based on de-facto industry standards. There is however the opportunity for third parties to produce translation layers for incorporation in machine controllers or FMIS PC environments where original manufacturers are unwilling or unable to provide a solution.

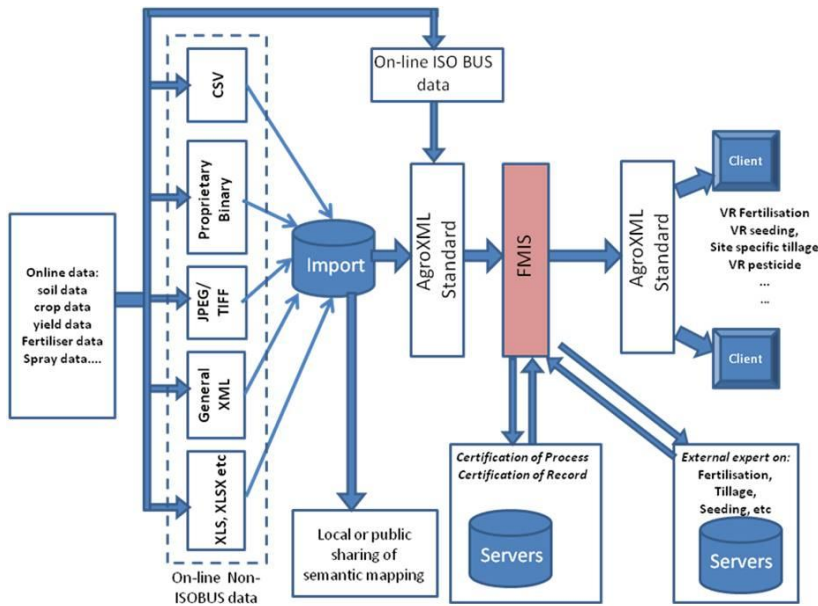


Figure 6: Logical routes for import of non-ISO data to FMIS

Concerning on-line sensor data acquisition, research within FutureFarm concluded the following :

- The preferred route for automated collection of on-line sensor data is the integration of sensors with ISO 11783 data network. This facilitates the adoption of the common agricultural data exchange standard. A relational database with the structure based on ISO 11783:10 task file is suitable for storage of acquired data. RelaXML tool provides user friendly data export and import between database and

TC.

- Non-ISO 11783 compliant sensor data is proposed to transfer into the FMIS ultimately as agroXML by using an import service based on local or public sharing of semantic mapping. The performance of the import service is the key challenge in management of sensor data.
- There is a significant potential benefit in time-saving from the adoption of standards to ensure robust transfer of in-field data. This may be directly accepted by farmers who already perceive information gathering to be the most time consuming element of field management.

3.4.2 Towards Automated Compliance checking

Production standards in the form of legal regulations or quality assurance labels are playing an increasingly important role in farming. Each farm must therefore gather information on all standards which apply, which may vary from field-to-field, and ensure that they are respected during operations. This information may be provided on paper or as electronic documents, by the standards publishers or by advisors. Together with the need to document compliance, the need to collect and process the requirements is becoming increasingly burdensome for farmers.

Within the FutureFarm project, scientific work done covered; the theoretical analysis of the existing standards, and their ability to be encoded in a machine readable form, and a proposed architecture for actually implementing the automated compliance. Specific parts of this architecture were implemented as proof of concept.

In the theoretical analysis conducted, two questions were addressed: whether an automation of the compliance checking is possible, in order to assist the farmer by proactively warning against 'forbidden' operations, and how the definition of the production standard may be formally represented in order to clearly and unambiguously inform the farmer as to what is required. This formal representation also forms one of the prerequisites for any automated assessment.

As an initial step, a general model of production standards was developed and applied to some common standards in European agriculture. Based on this model, separating standards into metadata and a list of individual rules (check points), a formal representation was developed and an assessment was made as to whether an automated compliance check was feasible.

The proposed architecture was built upon the analysis of the agricultural standards as well as the definition of the FMIS as a system of systems which integrates with different assisting services. Therefore, Service Oriented architecture was chosen. The proposed architecture included both the software components within the FMIS as well as the assisting service architecture outside the FMIS. To become more specific, it is agricultural organizations and



standards publishers that are expected to utilize this architecture in order to publish regulations and standards in a machine readable form.

Finally, a proof of concept implementation of the software was made. Selected rules and standards were encoded and made available through the FutureFarm website. Then, the FMIS component for the CLAAS information system was developed.

3.4.2.1 Analysis of agricultural production standards

An agricultural standard may be considered as being composed of a set of rules together with metadata describing the publisher, the intention of the publisher, the spatial and temporal range of validity, the target audience, procedures in the event of noncompliance, a definition of terms used. Additionally, each rule may have certain metadata attached to it regarding how compliance to that rule is to be assessed, and whether all rules must be complied with in order for the whole standard to be complied with or whether only a certain percentage of individual rules must be met. Each rule is effectively a predicate (i.e. a logical statement which may be evaluated to true or false), together with a conclusion (i.e. compliance or violation of the standard). Rules may be classified as either an obligation ('the standard is complied with only if the farmer does X'), or a prohibition ('the standard is not complied with if the farmer does Y'). Additionally, rules may require that particular actions are documented, whilst not proscribing how they should be performed. Although these may be considered as obligations, they are treated separately as they do not directly affect the decision-making related to field operations (e.g. the volume of nitrogen fertiliser to be applied). Individual rules may also be considered as having some metadata such as describing which operations they apply to, what data may be used to assess compliance etc. This model is presented graphically in

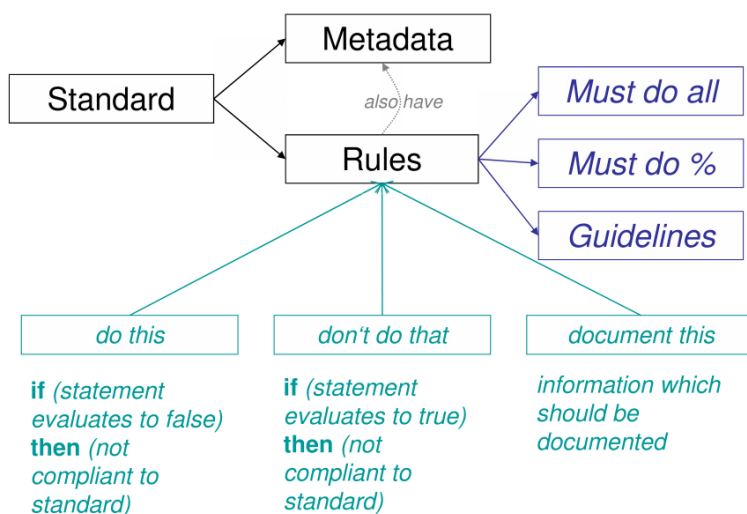


Figure 7: General composition of an agricultural management standard

software in the context in which they are used in the rule. Secondly, the rules must be computable, that is to say that it must be capable of being evaluated by an automaton (e.g. a Turing machine) according to computability theory

- Each rule must have a discrete outcome, which can be determined by a computer. That is to say that compliance to each rule must be assessed using computational models using digital data inputs and producing discrete outcomes (true/false) as opposed to value judgements.
- The required data inputs for assessment must be available in digital form at the point of assessment. This may be already existing data held in one or more databases which are accessible by the software, either internally or accessed via web services, or gathered on-demand by online sensors.



Three common agricultural standards were considered, namely the EU Cross-Compliance directives, the EU Organic regulations and the GlobalGAP standards for good agricultural practice. These cover mandatory rules for agricultural production Europe-wide, legally-regulated voluntary rules for products which are sold within the European Union and a private standard. The methodology for preparing the checklists is described in more detail in Nash et al., 2009a,b and Vatsanidou et al., 2009.

Following the above methodology, the quantitative evaluation of the rules from the regulations and standards Crops Base from GlobalGAP, EU Organic Regulation, and German D ngverordnung as an implementation example of the EU Cross-Compliance directives, namely the Nitrates Directive, was made. Firstly, each rule was categorised as to whether it represents an obligation, a prohibition or documentation for the farmer. Subsequently, four parameters were assessed relating to the possibility of formal representation (the first prerequisite), of automated machine interpretation (the second prerequisite), the objectivity of the required assessment (the third prerequisite) and to the availability of the required data (the fourth prerequisite).

The results of the analysis are presented in Table 4. It is foreseeable that much of the data which is currently available could in future be collected, managed and transferred digitally, thus allowing assessment of compliance to up to 90% of the agricultural production rules to be automatically performed.

Table 4: Determination of the potential for automated compliance assessment based on rule-by-rule assessment (Nash et. al 2011)

Standard	Parameter rule category	Formal representation [% rules]	Machine-interpretable [% rules]	Objective [% rules]	Data availability (available/foreseeable/unlikely) [% rules]
Crops base	Obligation/Prohibition (n = 98) (Documentation n = 22)	100	95	99	9/81/10
EU organic	Obligation/Prohibition (n = 74) (Documentation n = 12)	100	93	96	8/87/5
German D�V	Obligation/Prohibition (n = 29) (Documentation n = 3)	100	97	93	7/79/14
Overall	Obligation/Prohibition (n = 238) Documentation n = 37)	100	95	97	9/82/9

3.4.2.2 Formal encoding of agricultural production standards

The encoding of the agricultural production standards requires the encoding of the metadata for the agricultural standards themselves, as well as the formal representation of rules.

Metadata may be defined as a description of the actual contents, and thus the metadata here is a description of the standard which is necessary to understand its context and to evaluate whether it is relevant to a particular case. This includes common metadata terms such as publisher, date of publication, etc. as well as specialist items including spatiotemporal validity and relationships to other standards. There are many existing XML schema for metadata, such as Dublin Core (DCMI, 2004) and ISO19115 (ISO, 2003) but none of them cover fully the details for agricultural standards. One complication is the representation of the spatial region to which a standard applies. Two distinct categories can be identified; the production region (i.e. where the farm is located) and the end-product region (i.e. where the farm products will ultimately be sold to consumers. The first of these is relevant with respect to e.g. fertiliser regulations, which are valid for all farms within a particular country. The second of these is relevant for particular product standards e.g. organic production standards such as the EU organic regulations are valid for all products sold as organic in the European Union, wherever in the world they were produced. This requires the inclusion of separate meta-data elements for each case.

One criterion for enabling automated assessment of rules is that the terms used in defining the rules are defined in a machine-readable form. Also for a reliable manual assessment of rules, the unambiguous definition of terms is essential in order to avoid differing interpretations between those defining the rules and those assessing compliance. Ontologies are a tool for defining concepts, relationships and differences between them in a formal way, and have particularly risen to prominence as part of the semantic web (Berners-Lee et al., 2001). The most common language for modelling ontologies is the W3C Web Ontology Language (McGuinness & van Harmelen, 2004), which also provides an XML-based representation for interchange of ontologies, together with a functional, more human-readable syntax. There has been some recent interest in ontologies and their role in data exchange in the



agricultural domain (e.g. [FAO, 2010](#)), but there is no widespread acceptance of ontologies in practical use. However, many standards for agriculture include a definition of terms in the form of a glossary or legal definitions at the start of a text. These may be converted in a formal ontology with a little effort.

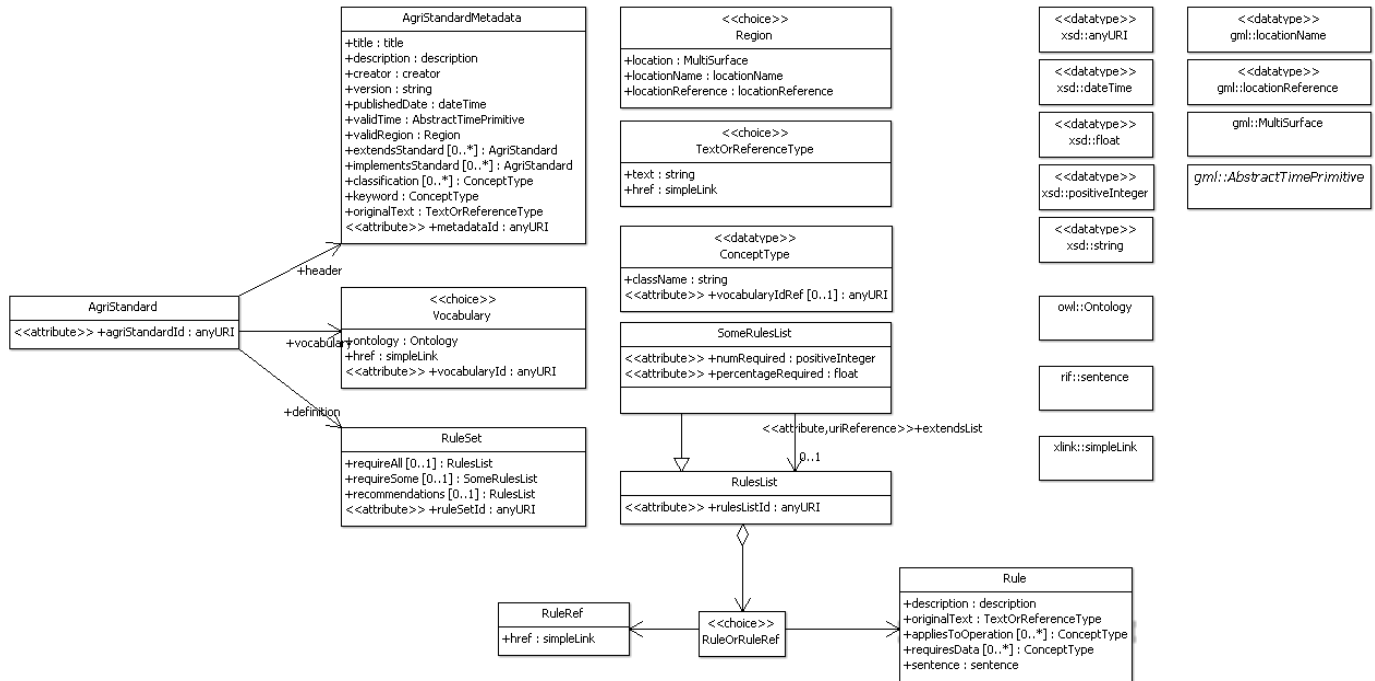


Figure 8: UML static structure model for the encoding schema (FutureFarm Deliverable 4.1.1)

Concerning the formal representation of rules, as a practical form for transfer between systems, the eXtensible Markup Language (XML) is the default choice for machine-readable representations. Although it is debatable whether all rules may be automatically assessed with any reliability, this does not mean that the rules may not be formally defined and represented, only that the interpretation may not always be done automatically ([Boer et al., 2007](#)). It is therefore assumed that those rules which may be straightforwardly and unambiguously interpreted automatically may be automatically processed, but that where this is not possible the definition of the rule, together with the relevant data, may be presented to the farmer or advisor in order to manually assess compliance. Furthermore, since the conversion of rules to a formal, logical-mathematical format is time-consuming and the main benefits will first be realised when the farm software is capable of reasoning with these rules, and farm systems are capable of automatically supplying all required data, it is proposed that in the initial stages, the formal representation of the rules should be optional, i.e. only the original natural language version of each rule must be supplied. This considerably lowers the entry barrier to producing standards in a basic machine-readable way.

There have been many proposals for formal representation of rules in XML, none of these have gained broad acceptance. A current initiative within the W3C is the creation of a Rules Interchange Format (RIF – [Boley et al., 2009](#)) which is, at the time of writing, at the ‘Candidate Recommendation’ stage. This allows the representation of rules as sentences based on the individual atoms, functions and predicates, which may be identified in their natural language representation and is expected to become the future standard for representation of rules on the Internet and in XML. As well as an XML-based format, the RIF defines a human-readable ‘presentation syntax’ based on the Extended Backus-Naur Form for context-free grammars.

Figure 8 represents the end result of the work done for the encoding of agricultural production standards; a UML static structure for the encoding schema.



3.4.2.3 Suggested Architecture of a system for automated compliance checking

In order to define the architecture of a system for automated compliance checking, a use-case analysis was conducted. Note that this use-case analysis concerns the Service Oriented Architecture -based system as a whole and not just the encoding format for agricultural standards. The diagrams are presented using the UML notation.

Four actors were identified who are involved in the system. Their names, roles, and the organisations and people who are expected to perform this role are described in Table 5.

Table 5: Actors in the proposed system

Actor	Role	Organisations
Catalogue Provider	The catalogue acts as a clearinghouse/search-engine for standards and repositories. Using the system of interlinked catalogues the FMIS may locate appropriate servers from which standards will be accessed. Each catalogue should contain metadata for a number of other catalogues and repositories. The catalogue provider will probably therefore be a semi-independent or umbrella organisation, not an organisation which directly publishes standards.	Government agencies, advisors, unions, collectives, ...
Standards Publisher	The organisation that defines the content of the standard. Note that they may not actually provide the standard themselves via a web-service/repository: this task may be contracted to a specialist organisation (which may provide this service for more than one standards publisher)	EU, national and regional governments, industry groups (label organisations)
FMIS	Tool used by the farmer to manage the farm, and in this case to find and use information related to standards	May be integrated in current FMIS (desktop or web-based) or a separate web-application for simple search-and-display functionality.
Farmer	Needs information about standards in order to correctly manage the farm. Could also be a farm advisor and not a farmer directly	Farmer, farm advisor
Autonomous farm machines	(Semi-)Autonomous farm machinery (e.g. robots) may require information about standards in order to implement an operational plan correctly and according to the standards. In terms of the use cases identified and presented here, autonomous farm machines may be considered as having the same role as the FMIS (client software) and/or the Farmer (actual decision-making)	Farm machinery

The software components which were consequently identified and which are shown in the use-case analysis are described in Table 6.



Table 6: Software components in the proposed system

Component	Role	Notes
Catalogue	Delivers metadata covering standards and repositories (servers) serving them.	It is not expected that a single catalogue holds all information about everything - a cascading system is envisaged whereby a catalogue may also be used to find further catalogues which hold information not held by the initial catalogue. There are therefore multiple catalogues in the complete system.
Server (repository)	Delivers information concerning standards. This information is the metadata describing the standard (also available via the catalogue) and the definition of the actual rules which must be followed to be compliant to that standard.	Each repository may hold information on one or more standard, and multiple repositories may be available.
Rules Application	Takes a rule definition and assesses compliance based on data from the FMIS and/or external sources (local filesystem, web services, wireless sensors, etc.)	The rules application may be implemented as part of the FMIS (either monolithic or as a software module) or as an external service (e.g. a web service).
FMIS	Client software which can query catalogues and repositories (based on certain parameters) to find further catalogues and repositories as well as to retrieve the definition of the individual standards, or even of individual rules which form part of those standards. The part of the FMIS responsible for managing interactions with Rules is referred to here as a Rules Manager.	More than one FMIS should be implemented within WP4 - a basic, web-based one which provides basic search-and-display functionality and one embedded within an existing FMIS which will be able to evaluate an operational plan against the standards.

The following use cases were identified.

1. Using catalogues to locate further catalogues holding metadata about available servers.
2. Using servers to retrieve metadata about individual standards.
3. Viewing information about standards and configuring the FMIS to respect chosen standards.
4. Using servers to retrieve the rules which are relevant for a particular context (e.g. planning or evaluating a particular operation such as fertilisation).
5. Testing a plan against rules retrieved from the servers using a rules application.

The first 3 should only be necessary on an occasional basis. Steps 4 and 5 will however be regularly repeated. The encoding to be developed here will be used for transfer mainly in steps 3, 4 and 5. Note that in this diagram the separation between the FMIS and the Rules Application component is not considered – i.e. a monolithic system is assumed in which the FMIS incorporates the Rules Application.

Concerning the software components of the proposed system, Figure 9 indicates the expected structure of the FMIS software. Two models of interaction between the FMIS/Rules Manager and the Rules Application are shown; ‘push’ and ‘pull’. In the first case, the FMIS identifies required data from the database and pushes this to the Rules Application. In the latter case, the database provides a standard interface which the Rules Application may use for querying to retrieve the required data.

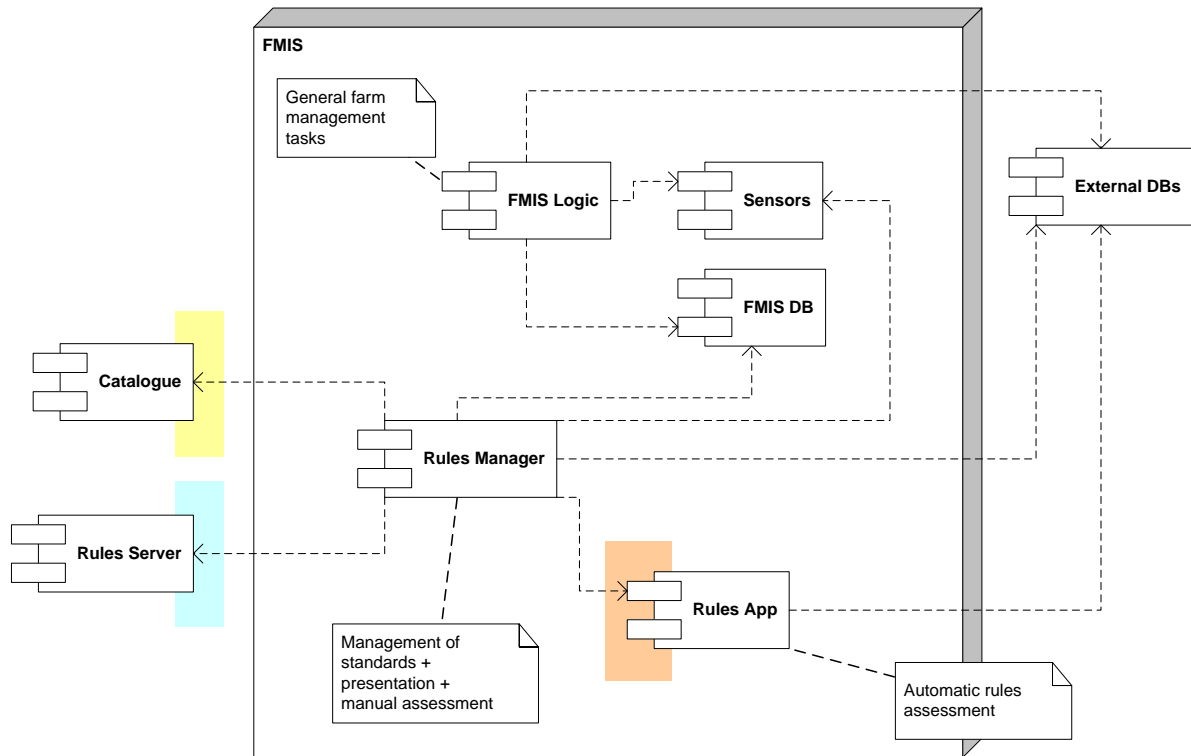


Figure 9: The planned overall system architecture for the incorporation of agricultural standards in the FMIS, presenting the relevant software components

3.4.2.4 Proof of concept implementation

In order to test and potentially prove the suggested architecture, a prototype implementation of the Catalogue and the Rules Server component was developed. The prototype is available for anyone to access from the FutureFarm website. This prototype includes selected agricultural regulations and standards in an encoded rules format. Details on the implementation can be found in FutureFarm deliverable 4.4 and 4.5.



Figure 10: FutureFarm Prototype web client to test a service for agricultural management standards presented in a machine-readable format

FutureFarm Standards Viewer Prototype

▼ **About this prototype**

English Deutsch

This prototype demonstrates how a client may use catalogues and rules servers complying to the specifications developed within the FutureFarm project in order to discover and download standards defining the rules with which the farmer must comply during farm management and operations. These rules may be legal requirements such as fertilisation laws, voluntary standards to demonstrate good agricultural practice such as GlobalGAP or specialist standards for certified produce e.g. for organic production.

In this prototype, the querying of catalogues and rules servers based on simple search parameters such as the region in which the farm is located, the type of standard which is of interest and the current operation. The prototype guides you through the process of searching to produce the list of rules corresponding to the standards you operate to on your farm.

In future, this searching could be included in your normal farm management information system, with the rules being encoded in a machine-readable format so that your FMIS can automatically test for compliance with them.

Return to main FutureFarm site

▼ **Disclaimer**

English Deutsch

In order to demonstrate how this system may work in future, it is necessary to simulate a number of catalogues and rules servers. To indicate who may provide these in future, the catalogues and servers are shown as being run by various organisations. None of the organisations represented is connected with the FutureFarm project or endorse the results shown here. Similarly, the representation here of an organisation is not an endorsement by the FutureFarm project.

The standards and rules represented in this prototype are provided for demonstration purposes only, and in some cases are based on our interpretation of the official documents. No decisions should be made based on this information.

In future, we hope that standards publishers really will deliver standards in a machine-readable form using the specifications demonstrated here!

Furthermore, an FMIS client was developed for the CLAAS FMIS. CLAAS has been a partner to the FutureFarm project.

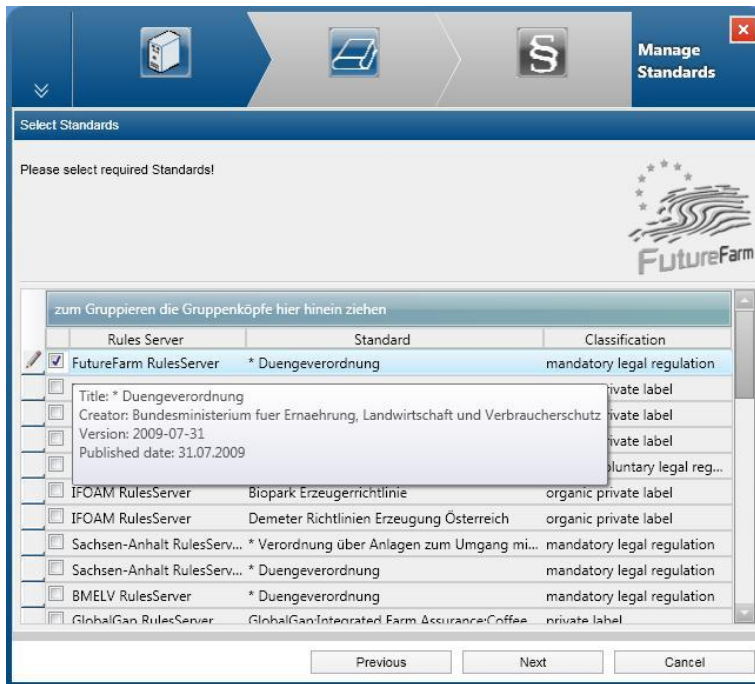


Figure 11: Agricultural management standards implemented in the CLAAS FMIS. A Screenshot

The analysis of the feasibility of automating compliance assessment showed that conceptually the biggest hurdle is the availability of digital data, with very little of the required data currently available.

However, automated digital data collection is becoming more widespread, e.g. due to the use of ISOBUS-compliant hardware, information-intensive precision farming techniques, wired and wireless sensors, etc. (Sorensen et al., 2010). Farmers are therefore increasingly likely to gather digital data on all aspects of the farm. This data must however be managed and, if necessary, transferred between components of the system. An improvement in agricultural data management

and a standardisation of data transfer mechanisms is therefore a prerequisite for automated compliance assessment.

An improvement in agricultural data management and a standardisation of data transfer mechanisms is therefore a prerequisite for automated compliance assessment.

Since the rules change periodically, and as discussed above, must currently often be inferred from the standards, a mechanism is required whereby published changes are automatically detected by the software. A web-service based system whereby each standards publisher may provide a standardised representation of the rules directly to the software will provide such a mechanism. However, this presupposes that the standards are published as individual rules, that there is a standardised format for these rules and a standardised web-service interface with which to access them. Currently none of these is the case.

However, this work illustrates that such an approach is feasible: the existing standards and regulations may be rewritten as formal rules, which in turn may be represented in a format suitable for machine-machine communication and even automated interpretation.

The technical basis for such a system is available: what is more questionable is whether this system will be accepted by the bodies that publish the agricultural rules. The move from publishing regulations as legal texts to publishing as individual rules in a machine-readable format is a large change in procedure which would require significant political will to make.

The FutureFarm project provided a practical demonstration of the potential benefits of such a system; the FutureFarm consortium hopes that this will be able to influence decision-makers.

If software is to be able to flexibly interpret rules, it is therefore necessary that the vocabulary used is known to the software. A harmonised vocabulary covering all agricultural rules and data standards would ensure this, but is probably unrealistic in practice. The expression of vocabularies using formal ontologies, and the use of mappings (so-called 'ontology alignment') between these and inference engines is a more realistic solution, albeit one which would require significant developments from the current situation. However, there are a number of recent approaches using ontologies in agriculture, and they are already in widespread use in other fields (notably life sciences, see also <http://www.obofoundry.org>). A transfer of such techniques to the agricultural sector is therefore feasible.



3.5 Socioeconomic aspects of the use Information and Communication Technologies in the farm

In the FutureFarm project context, farm information systems and precision farming technologies are considered to be closely interlinked and supporting each other. Therefore, although existing information systems were also assessed in respect of their current socioeconomic impact, special focus was also given to the currently existing in the European market precision farming technologies.

The issue of the adoption of these technologies was also addressed within the project; both the potential of such an adoption per European region was assessed and the way that farmers end up (or not) in adoption decisions and the extent to which such decisions are influenced from the farmers' communication and cooperation strategies.

3.5.1 Current and potential use of Precision Farming and Information Systems: The farmers' view

Findings from a survey in Denmark, Germany Finland and Greece in the Future Farm project show that farmers use various farm management information systems and precision farming systems on their farms ranging from automated data acquisition systems to advanced robotic systems. In Finland, only a few respondents use GPS and auto guidance systems. The study shows that 4 %, 24 % and 12 % of the German respondents use GPS, auto guidance or a combination of GPS and auto guidance respectively. A similar distribution for Danish respondents is 4 %, 2 % and 4%. The potential for using administrative and farm management systems can to some extent be related to hours spent at the farm office. Danish and in particular German respondents use a significant amount of time weekly i.e. 7 and 20 hours respectively on office related tasks, including time spent in activities related to area subsidies and learning new procedures. In Finland and Greece, farmers spend respectively 3 and 1 hour per week. Hence there seems to be a potential for labour savings in using farm management information systems for budgeting procedures, field planning and for replacing paperwork to deal with subsidy applications and public authorities. There is a variation on the hours spent in the office for administrative tasks but it is not clear which is the profile of the farmers that spend less or more time at the office. However, there seems to be a potential to reduce the labor time spent on administrative tasks by using information systems. In northern Europe most of the time is spent on accounting tasks but also field planning and consulting/negotiations. In Greece less time is spent on average on accounting. For most farms the adoption of automatic systems causes a moderate reduction of total weekly office hours spent at the farm.

More detailed information on the farmers' assessment of the information systems that they currently use as well as their future expectations were retrieved by interviewing the project's pilot farms.

In order to support these interviews, existing agricultural systems that are used by the pilot farms were categorized on the basis of their level to: **macro, farm, and micro level**. Macro level includes systems which supply communication with the surrounding world. Such systems can provide information such as yield forecast, prices and predicted prices, weather information, as well subsidies information and communication with the respective authorities about subsidies. Farm level systems are oriented to farm management, including accounting, ERM, logistics, machinery. They also include other tools managing information for the farm as a whole, or managing information up to the level of a single field. Finally, as micro level systems are characterized the systems which are focused on supporting the decision making inside one field; usually these are classical systems focused on precision farming.

The interviews with the pilot farms revealed that flow of data and information is difficult between the systems and subsystems in the macro, farm, and micro level. Even when such information flows are supported, they are usually only to one direction. Examples could be the subsidies systems or the traceability systems. In those systems, information from fields is transferred on farm level and then is used for the control of subsidies or for retrieving information on the market. The expectations of the farmers from ICT systems in the future were also derived. Farmers expect in the future:

1. ICT applications for the complete traceability of production, products and services throughout a networked value chain including logistics;



2. Collaborative environments and trusted sharing of knowledge and supporting innovations in agri-food and rural areas, especially supporting food quality and security;
3. ICT applications supporting the management of natural resources and rural development.
4. ICT applications reducing administrative burdens in rural areas

3.5.2 Socioeconomic impact from the use of precision farming technologies

The farm size was found crucial for the use of precision farming and ICT. Advanced information systems and precision farming systems are mainly aimed for large scale farming. There are clear scale advantages of using precision farming systems. It also appears however, that small farms have a larger potential to improve/save the use of time from administrative tasks compared with larger farms.

The socioeconomic consequences of full implementation and controlled traffic have been made for Denmark as a case. Findings show that the socioeconomic consequences are small but positive on GNP and domestic consumption. The improved productivity in the farm sector leads in general to a higher production with socioeconomic benefits. The consequences are small but in effect it leads to minor increase of production costs in sectors that are not closely related to the farm sector. In relation to agriculture it shows that the payment of land (compensation of land) increases. In addition, the overall use of pesticides is expected to decrease with PF.

3.5.3 Energy Analysis for agriculture: mitigation strategies and technologies

Within the FutureFarm project, a holistic view of the farming system was attempted taking into account the available technologies, including the information systems. The issue of the energy consumed for agricultural purposes was therefore investigated and there has been attempted to identify whether precision farming and ICT technologies could have an impact on the farm energy consumption. Therefore, direct and indirect energy use in arable farming was analyzed. Denmark and Greece were used as example cases. Based on this analysis, suggestions for mitigation of energy use were made.

The energy analysis of Denmark revealed that ploughing ranks first amongst the direct energy costs and use of artificial fertilizers and crop protection chemicals rank high on the list of indirect energy use. Under Greek conditions, depending on the crop, irrigation and ploughing compete as direct energy costs. Similar as in Denmark, fertilizer use and chemical crop protection rank high on the list of indirect energy consumption.

Mitigation strategies for direct energy consumption include:

1. Reduction of irrigation. In Denmark, this might be an option. For Greece this is no option, since there agricultural production is largely based on irrigation.
2. Reduction of ploughing, by implementing no-till systems.
3. Improved field management, including implementation of soil structure preserving measures such as using the correct dimensions for machinery, tires and their pressure (reduced ground pressure; RGP), controlled traffic farming (CTF).
4. Yield increase, which would reduce energy consumption per unit of product.
5. Changing the source of energy. The efficiency of diesel engines has not shown much improvements past decades. Hydrogen driven tractors might make a difference. Also electricity driven vehicles would be valuable option, yet the generation and long term storage of energy still is a challenge.
6. Mitigation strategies for indirect energy consumption include:
7. Reduction of artificial fertilizer for instance by implementing organic farming
8. Alternative tilling strategies would reduce indirect energy use as well, yet it might enhance the use of chemical crop protection.

Following the energy analysis, the potential of on-farm biofuel production was investigated and numerous results were retrieved:

In-farm vegetable oil production is feasible with simple means. The most prominent candidate crops for such production are sunflower for southern Europe and rape seed for northern Europe From these crops oil that can power farm tractors with diesel engines can be produced. Both crops have a clear positive energy balance under



European conditions. Up to 6.1% of the farm land can cover the requirements of crops without irrigation; but up to 15% is required to cover the irrigation needs as well. Additional amounts of feedstock from the press cake and solid biomass from the crop stalks can provide animal feed and heat for residence, offices or greenhouses.

Based on the results, a direct energy independent farm is feasible. This farm would save significant amounts of energy; a considerable contribution to the achievement of the EU targets. What is more, a clear economic benefit for the farmer will be created. Concerning the emissions, use of vegetable oil might yield a higher NO_x emission but a lower pm emission as well as lower CO₂ emissions will be accomplished.

The potential of fleet management to reduce energy consumption and costs was also investigated. A literature review has revealed what the research community has shown to be possible for planning and managing the operation of teams of conventional and semi-autonomous machines. Currently available commercial technology for planning and managing the operation of agricultural machine fleets was identified, as well as the limitations of currently available commercial research-prototype systems. Finally, recommendations were made for bridging the gaps between what is commercially available, and what constitutes state of the art in research. A roadmap for what needs to be developed further was also delivered.

A comparison of optimal field planning with practical field planning schemes revealed a fuel saving potential of 10%. Computational and communication requirements for fleet management were analyzed. It was concluded that due to computational complexity, computation of fleet management strategies will not be performed on board the machines but at by a central processor, the dispatcher. Band width requirements were analyzed in view of data transmission requirements.

3.5.4 Precision Farming adoption aspects

3.5.4.1 Assessment of the potential in the EU states

The necessity of a study for potential of the adoption of Precision Farming in Europe can inspire relevant policies and support targeted adoption campaigns. To this end, the way farmers are informed and communicate with each other was also studied.

The assessment was produced by using European statistical information of EUROSTAT to conduct a potential analysis assessing the potential of PF on level NUTS 2. Characteristics for a certain PF-potential are mentioned in the literature: field heterogeneity, management intensity, farm size, cereals and vegetables. No statistics related to the field heterogeneity are available in EUROSTAT, so that this factor is not being considered in the potential analysis.

Universal valid rules were ascertained to reflect the PF-potential of regions: the more cropland, the more cereals, the more hectares per worker and the more economic powerful a region, the higher the PF-potential. Based on these pre-requisites a potential analysis was conducted with the help of following five indicators: cropland / total area [%], farms with cropland / all farms [%], cropland / farms with cropland [ha], farms > 16 ESU / all farms [%] and farmland / worker [ha/worker].

The conducted potential analysis considering the above listed indicators results in four classes of PF-potentials: very high, high, medium and low. The very high potential is focusing on the central parts of Western Europe, especially the north half of France, the east coast of England and Scotland, south Sweden, Denmark, the north and east of Germany and a few regions in the Netherlands and Belgium, one region in the Czech Republic and one in Spain. The high potential is also focusing on the countries in the north and west, while the medium and low potential is predominantly located in the periphery of Europe, like the Atlantic coast and the Mediterranean, and with a few exceptions in the new member states of central and east Europe.

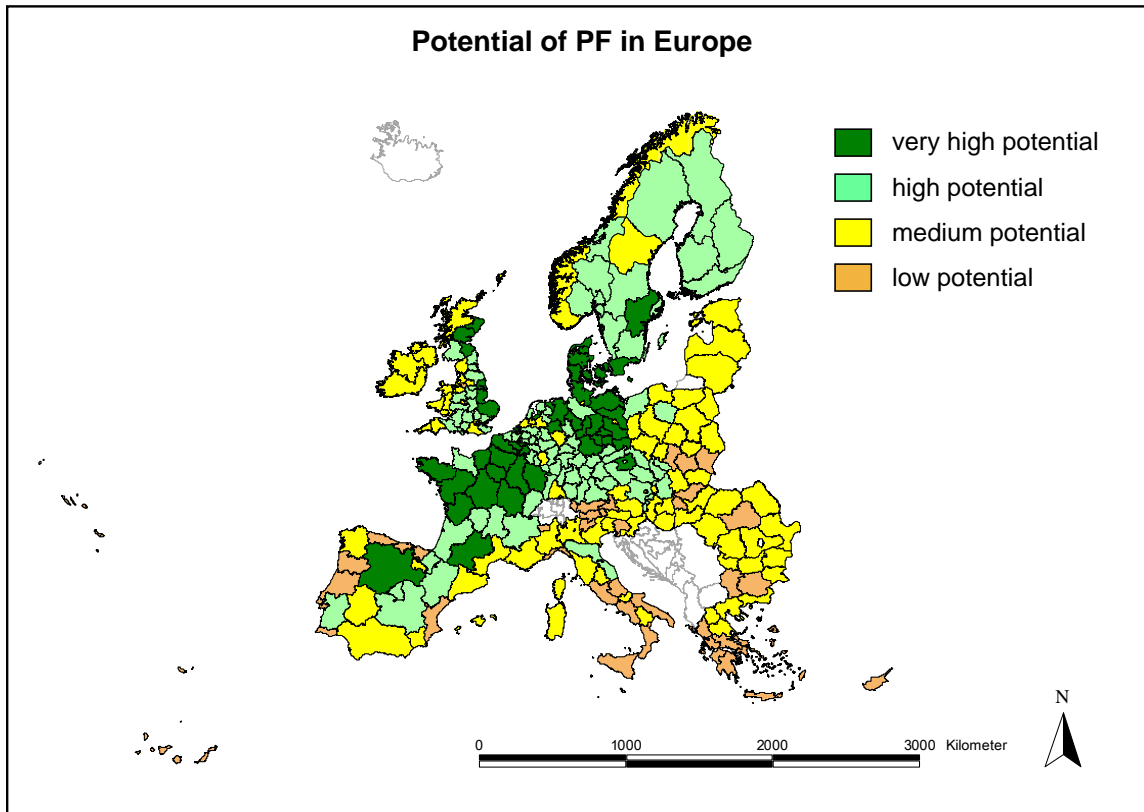


Figure 12: Potential of PF in Europe

3.5.4.2 Farmers' communication and cooperation strategies in respect of the PF adoption

In order to support further campaigns, the importance of **farmers' communication and co-operation strategies** in the adoption of Precision Agriculture (PA) was analysed by another field research study. Forty-nine qualitative interviews with stakeholders from the agricultural sector were conducted. The survey was based in Germany where most interviews took place and reflected with findings from the Czech Republic, Denmark and Greece.

For stimulating the adoption of site-specific farming technology, professional literature, exhibitions and field days are of major importance. Communication habits in agriculture may change in the near future due to a need for exchanging increasing amounts of data. Web services and e-mail play an increasing role as a tool for farmers. In Germany and Denmark, communication between farmers and authorities could shift towards online technologies within the next 10 years. We assume that this process is slower in Greece. It may increase between farmers and consultants or contractors.

Farm data is considered sensitive and fears of data misuse are widespread. Farm sizes influence the communication and co-operation patterns of agricultural enterprises. While large farms employ specialized staff and preferably own their technology, joint investment in site-specific technologies are an option for smaller farms.

Farmers frequently operate as contractors themselves to use their PF machinery to their full capacity. The role of contractors in PF is only marginally covered in the literature. Agricultural contractors were considered as a major driving force behind PF in the next 5–10 years, especially in areas of small farm sizes or high concentration of livestock farming. Contractors, who usually operate with modern technology and due to scale effects, have the possibility to employ specialized staff. There is a tendency towards offering field services and consultancy at the same time. Industry will have to increasingly face the requirements of this group regarding compatibility, software solutions and data management.



4 Potential Impact and main dissemination and exploitation activities

The reform of CAP beyond 2013 is a major issue for the agricultural industry around Europe. It is anticipated that the new CAP will be focused on a “new type” of agricultural development which will be safeguarding the environment including the European soil and water reserves by utilizing new technologies for more efficient management and controlling the usage of pesticides and fertilizers. The farm of the future should be complied with standards to ensure competitiveness in international markets as well as sound environmental standards, as well to be targeted to farmers’ personal management strategies with strong communication and cooperation mechanisms. A number of standards are available at Global, European, National, Regional and Terrestrial level. However, all these are difficultly implemented in the farm level since the majority of growers are not familiar with these rules. Moreover, simple farmers are not used to keep up with regular basis records of their production chain. A simpler procedure is needed for the correct and more efficient implementation of these standards in the production chain.

4.1 Standards and Rules

The analysis of the most important standards and rules and the development of relative vocabularies will help growers, farmers and other relative stakeholders to be better informed with the new rules. Moreover, the categorization of the rules into the major field applications can be used in various ways from simple ICT application for standards and rules implementation to their incorporation to more general FMIS tools. Such a management practise will lead to a more efficient use of input and to a more environmental friendly agriculture. In the same line, the identification and analysis of farmers’ personal management strategies in accordance to the information needs could enable for transformation of this tacit knowledge into sophisticated FMIS. This will also has an impact in the extension service to better target their services to the actual farmers’ strategies tailored to their beliefs and not following a blanket approach generating services to all farmers. The impact of the requirements for Farm Portal is also significant as generic farm portals should be generated for the multifunctional farms of the future. This will have an impact in the whole agricultural supply chain from the farmers, traders, retailers, consumers, advisory bodies, legislation bodies and governmental agencies. A farm portal to link with traceability systems are of high importance and the security of data should be taken into special consideration. Finally, from the study on farmers’ communication and co-operation strategies, the impact lied in the role of agricultural contractors as a major driving force behind PA in the next 5–10 years, especially in areas of small farm sizes or high concentration of livestock farming. Contractors, who usually operate with modern technology and due to scale effects, have the possibility to employ specialized staff. There is a tendency towards offering field services and consultancy at the same time. Industry will have to increasingly face the requirements of this group regarding compatibility, software solutions and data management. The particular means of communication and co-operation among contractors, farmers and the industry should be examined in order to enhance the adoption of PF.

4.2 The new model of a Farm Management Information System

A new model and prototype of a new Farm Information Management System (FMIS) integrating information systems to advise managers of formal instructions, recommended guidelines and documentation requirements for various decision making processes has been designed. The proposed FMIS meets the requirements of future and current European farmers in terms of enhancing their managerial tasks as related to economic viability and the interaction with the surroundings. This research has shown the impact of using dedicated system analysis methodologies as a preliminary step to the actual design of a novel farm management information system compared with other more rigid and activity oriented system analysis methods. Also, it has been shown that the use of the soft system approach allows a fundamental analysis, incorporating the identification of required changes and most importantly, the unstructured analysis enables the identification of existing constraints, and possible solutions, which may not be apparent using more structured methods.

Complementary to the model identification of the proposed FMIS, the information flows for targeted field operations has been presented through a user-centric approach. The information models are centred on the farmer as the principal decision maker and involves external entities as well as mobile unit entities as the main information



producers. This is a detailed approach to information modelling that enables the specification and documentation for the generation and implementation of a Farm Management Information System in crop production.

4.3 The proposed Service Oriented Architecture for the future FMIS

Within the project, the prototypic implementation of concepts for a flexible and modern Farm Management Information System was made by using state of the art techniques. These techniques have the potential to serve as basis for the creation of distributed applications in the agricultural domain. One aspect during the development process was to choose the concept of a Service-Oriented Architecture, which consists of different parties with Service Providers, Service Brokers and Service Consumers (Figure 13).

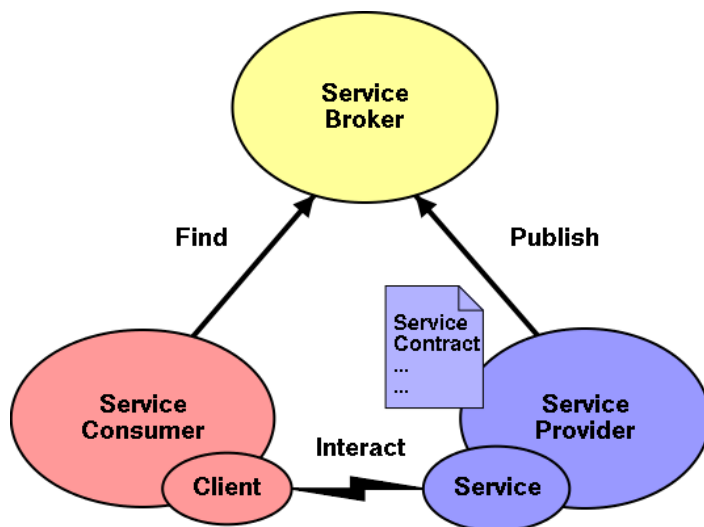


Figure 13: Service-Oriented Architecture (Source: Haas, H. 2003 available at <http://www.w3.org/2003/Talks/0521-hh-wsa/slide5-0.html>)

In the use case “Integrating Knowledge for Compliance to Agricultural Management-Standards” the Service Consumer is mainly seen in the user of an FMIS (e.g. the Farmer) but is not restricted to one party. Service Providers in this case are the Management Standard Setters, namely governmental institutions or publishers of private management standards. Agricultural Service Brokers help to find the Services by Service Consumers, e.g. agricultural organisations or similar could be appropriate for this part. The

Service Providers agree on a common data exchange format for the specific service as it was proposed by FutureFarm (see also FutureFarm Deliverable 4.1.1 and 4.1.2). As the FutureFarm Partners expect various services which are based on knowledge and handled by rules in future, the machine-readable encoding of agricultural standards consists well known terms from domain agricultural and rules to describe what is allowed and forbidden by the management standards. The terms might be described in suitable formats (e.g. W3C OWL) and in freely accessible repositories in order to keep them reusable by various future applications. To test the proposed architecture, a prototype including example data sets was developed and disseminated via the FutureFarm website (<http://test.futurefarm.eu>).

All of these prototype services have a RESTful interface as this web service design paradigm seemed to be appropriate for this kind of services and makes it easy for developers of Farm Management Information Systems to integrate such services in their client software. Therefore, the necessary libraries for the .Net-Framework have been developed to give developers of FMIS for the Microsoft Windows Platform easy access to the services.

The main impact was to attract developers and experts from the agricultural domain to use such a service in further applications. A first draft prototype of a Rules Interpreter Component was developed, enabling FMIS to automatically check compliance to the management standards served by the proposed architecture. Feedback has been received by showing a high strategic potential of such services, but there have to be taken a lot of efforts on the organisational and administrative side to practise such a generic service.

4.4 Energy on Farm

On-farm production of bio-fuels offers a lot of potential advantages like the independence from oil shortages possible in the future, an important contribution of the farms in reducing CO2 emissions and contribute to the targets set by EU and an additional income to the farmers and rural areas an important factor to maintain farming communities in rural areas. Assuming that direct use of vegetable oils is technically and practically possible, an



energy self sufficient farm can be developed. Based on the crop yields achieved and the oil extraction by cold pressing efficiency a part of the farm ranging from 6 to 12% devoted to energy crops can cover the liquid fuel requirements of a farm.

Besides on-farm biofuel production, reduction of on-farm energy use is a way to improve the sustainability of arable farming. Under conditions in Northern Europe, ploughing is amongst the main direct energy consuming activities. The use of artificial fertilizers ranks high on the list of indirect energy consumption. No-tillage farming seems a suitable alternative. Under south European conditions irrigation is besides ploughing the energy consuming activity. As water is a strongly limiting factor under these circumstances, suitable mitigation strategies will be hard to develop.

Fleet management in arable farming still relies strongly on human supervision and decision making. Yet, with growing farms, growing machine fleets and growing associated costs of mechanisation, effective use of these resources is required. Fleet management techniques based on mathematical optimization principles may lead to significant reduction in time and energy use. Energy savings in the order of 10% are expected. Automatic fleet management will require more and automated information exchange and data processing. As significant computing power is needed and this currently exceeds commonly available computing power of current board computers, computing for fleet management may require a centralized approach. Management strategies are generated on a central computer and distributed amongst the individual vehicles in the fleet through the wireless network. Current developments in wireless networking and networking configurations support the developments in fleet management.

A next step in farming might be or, to put it more strongly, will be the replacement of human operated machines by robots. Though this technology is not yet mature, progress is considerable and will change arable farming in the coming decades.

4.5 Recommendations

To increase the adoption of advanced information management systems and precision farming systems, the futurefarm consortium recommends that the national and regional farm advisory services are strengthened in order to guide farmers in the use of advanced farm information systems. Particular concern will have to be made for the farms with smaller production scale. We further recommend that new advanced information systems are developed to cover the needs of smaller farm units. Farmers should be encouraged to cooperate in order to utilize farm software and hardware more efficiently. Software programs should be user-friendly and farmers' inherent knowledge has to be taken into account when designing the programs. Each farmer has often specialized needs, which depend on his field planning activities, crop rotation, technical insight and management strategies.

Farm information software should be designed to match certain regional and agronomic characteristics as well as farm management practices.

During the course of the project, it became evident from the discussions with the farmers that further specific research should be put into autonomous and visual crop detection and crop modeling in order to model nitrogen response and weed development in combination with the water response functions.

To improve a further adoption of farm management systems, advisors and farmers and researchers should continue the development of sound decision support systems that combine financial/economic management and in-field management, incl. weather forecasts, soil-structures and the field history. Farmers need clear proofs that show yield improvements and economic improvement from variable rate technologies. Given a continuous change in weather conditions, decision support should rely on dynamic data rather than historic field data together with financial planning tools.

Concerning the FMIS, the presented model was centred on the farmer as the principal decision maker and involved external entities as well as mobile unit entities as the main information producers, as a way to extend the general proposed farm management information system design into automated decision-making. Furthermore, for the better process control as well as an improved capability of documenting the quality of farming, farmers would be



able to gain increased insight into their production processes and would be able to evaluate the performance of the chosen technology.

The envisioned assisting services will be arranged as a manual/personal service for the farmer, involving possibly semi-automated parts, or it will be fully automated (software implementations) depending on the level of knowledge modelling of the relevant decision process as well as the level of data quality and availability.

By inferring from the FMIS functionalities to the actual FMIS architecture, a network of distributed web services, which offer the required functionality, comes up as a possibility. The implementation of these services may vary and will depend on elaborated information flows. A major requirement would be that all services communicate via well-defined open interfaces and agreed upon vocabularies, enabling a cost-efficient implementation of the architecture. This communication will be accomplished only if semantic technologies are used.

The use of semantic technologies relies on a seamless and standardized data transfer. This is a prerequisite of highest priority in order to enable future knowledge based applications. The use and (collaborative) development of shared vocabularies should become widely adopted in the mid-term in order to avoid obstacles due to ambiguity and translation.

The different kinds of rules and logics for various purposes of knowledge management in agriculture have to be investigated in more detail. Furthermore, it is essential for a widespread acceptance and reuse that there is open online access to rules. Such rules may evolve from a “testing” to an “approved” level. During the formulation of rules it would be of great benefit if a following evaluation process is considered, e.g. that rules include definitions of how compliance should be assessed. Therefore, rules could have different representations for machine evaluation, lawyers and end users.

4.6 Dissemination and Exploitation Activities

Dissemination activities have included presentations in conferences, papers in scientific and technical journals, and presentations to special groups such as farmer’s consultants, agriculturist, farmers and relative SMEs focussing on information and communication technology in the agriculture sector. A detailed list of all the dissemination activities of the project as well as the scientific publications resulting from it is included in the next section of this report.

FutureFarm partners participated in all major scientific conferences of the last three years disseminating the project’s results.

The FutureFarm project conducted in Nov. 2010 in Cologne, Germany a new type of R&D-conference for information management in agriculture (GeoFARMatics 2010). On that conference many researchers, public administration and companies met to discuss the results of FutureFarm and to hand over results and strategic thinking from FutureFarm to participants of the EU-project agriXchange. The public “Cologne-declaration” summarizes state of the art in R&D&I and addresses public administration, politicians and funding authorities with requests for future steps to implement proper ICT, especially information standardization in agriculture.

Stakeholder workshops were organized in Germany, Denmark and Czech Republic. Except from scientists, some farmers, farm consultants as well as professionals from the public authorities from each country participated. The potential and also the hindrances of adopting the proposed architecture for the automated exchange of rules and standards in agriculture was discussed. It is currently investigated whether pilot projects can be established in Germany and Denmark.

Farm field days took place in the three project’s pilot farms, i.e. in Germany, Czech Republic and Denmark during 2010. In Greece instead, a special session for FutureFarm was held during the Annual Conference of the Young Farmers Association.

FutureFarm participated also in the Agritechnica Fair, which took place in November 2009 in Germany. During the Fair, FutureFarm partners had the chance to present the proposed FMIS architecture to the industry and more specifically to the agricultural machinery providers. The latter target group have acknowledged the derived



information model as a way to identify new development objectives when looking at automated decision making in the future within agriculture.

Providing specifications for specific implementations of the FMIS within the FutureFarm project resulted in the addition of the RulesManager component's in the CLAAS agricultural software.

The Joint International Agricultural Conference (JIAC2009) held in Wageningen, in July 2009, included two FutureFarm special sessions. During the same conference, a demonstration of the current state of the art in field robotics and a Field Robot Event competition was organized with the support from FutureFarm. The conference, except from the scientific community, attracted the attention of the local and international press.

4.7 Contact List

The FutureFarm project involved the following organizations, which can be contacted directly in case further information for the project's results are requested.

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Additional information about the project as well as the project's deliverables can be found at the project's website at www.futurefarm.eu.



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