Chapter 9
Future Perspectives of Farm Management Information Systems

Zisis Tsiropoulos, Giacomo Carli, Erika Pignatti, and Spyros Fountas

Abstract Farm Management Information Systems (FMIS) have evolved from simple record keeping to sophisticated solutions able to capture new trends involving spatial and temporal management, distributed sensors involving interoperability of sensing devices, future internet applications and web services. The FMIS were initially designed to deal with the farmer as the main focus of the system, whereas now data flow from and to the tractor information board, and connections with other pieces of equipment such as precision agriculture devices can be managed through an FMIS. This pathway of evolution has led to the inclusion of a rich set of functionalities and opened up the possibility to improve the cost control of farms. In this chapter, we present the state-of-the-art on these topics depicting the new functionalities included in evolved FMIS and how they can connect the farm to the external context and stakeholders. Then, we delve into the costing functionality of FMIS to understand how precision agriculture can improve the allocation of costs to final products. Finally, we conclude our discussion on the process of adoption of FMIS in European farms.

Keywords Farm management information systems • Precision agriculture • Stakeholders • Adoption

---

Z. Tsiropoulos (✉) • S. Fountas
Agricultural University of Athens, Athens, Greece
e-mail: tsiropoulos@teilar.gr; sfountas@aua.gr

G. Carli
Department of Strategy and Marketing, The Open University Business School, Milton Keynes, UK
e-mail: Giacomo.Carli@open.ac.uk

E. Pignatti
Check Fruit-NSF Italy, Bologna, Italy
e-mail: e.pignatti@nsf-italy.it

S.M. Pedersen, K.M. Lind (eds.), *Precision Agriculture: Technology and Economic Perspectives*, Progress in Precision Agriculture,
https://doi.org/10.1007/978-3-319-68715-5_9

9.1 Introduction to Farm Management Information Systems

The tremendous progress on technological advances in computers and electronics in agriculture in the last decades has brought significant changes in working environment for the farming community. This has generated a vast amount of data to be used by farmers and the challenge is the best exploitation of these data to make useful and practical information available for crop production. The farm manager of today has to choose among different vendors of technologies and data providers to use the most appropriate information to make the best decisions for his or her farm. Decision making is a crucial component for the farmers and many researchers have studied it in relation to the availability of providing data (i.e. Fountas et al. 2006; Magne et al. 2010). The most important aspect of carrying out research in farm management decisions is to understand the tacit knowledge of farmers, and how farmers react when a decision should be made (Gladwin 1989). This is the most important direction that researchers working with data management in agriculture should pursue to provide farmers with the information they need to enhance decision making at specific stages of their production process.

The basis for efficient decision making is availability of high-quality data. In Europe, most of the farms are having difficulties in using the available data and information sources, which are fragmented, dispersed, difficult and time-consuming to use. This indicates that the full potential of these data and information are not well utilized by farmers. The integration of historical data, real-time data from various farming sources, knowledge sources, compliance to standards, environmental guidelines and economic models into a coherent management information system is expected to remedy this situation (Fountas et al. 2005).

Farm management information systems (FMIS) have advanced from simple farm record-keeping systems to large and complex systems in response to the need for communication and data transfer between databases to meet the requirements of different stakeholders. The FMIS are electronic tools for data collection and processing to provide information of potential value in making management decisions (Boehlje and Eidman 1984). They exist when main decision makers use information provided by a farm record system to support their business decision making (Lewis 1998). In a more detailed expression, FMIS is defined as a planned system for collecting, processing, storing and disseminating data in the form needed to carry out farm operations and functions (Sørensen et al. 2010). Essential FMIS components include specific farmer-oriented designs, dedicated user interfaces, automated data processing functions, expert knowledge and user preferences, standardized data communication and scalability; all provided at affordable prices to farmers (Murakami et al. 2007). The FMIS have evolved in sophistication through the integration of new technologies, such as web-based applications and applications for smart phones and tables (Nikkilä et al. 2010).

A key question has been whether commercial FMIS have been able to capture the functionalities developed in academic research, such as an indication of the level of transferal and uptake between research and commercial systems. Another question is whether the increased demands from data intensive Precision Agriculture services is being met by current commercial FMIS systems. Such a comparison between academic with 141 commercial FMIS applications was carried out by Fountas et al. (2015a). Their study revealed that commercial applications mostly deal with data processing for everyday farming activities, whereas academics still explore new horizons in research with high sophistication and complexity, capturing new trends involving spatial and temporal management, distributed systems involving interoperability of sensing devices, future internet components and web services. Commercial applications tend to focus on solving daily farm tasks with the aim to generate income for the farmers through better resource management and field operations planning. The advances that are needed in the development of FMIS include improvements in technology, adaptation motivation, specific new functionalities and greater emphasis on software design governed by usability and human–computer interaction. The diffusion of information management as business innovation in the farming community could benefit from the comprehensive research developed in the last few decades on the adoption of Information and Communication Technologies (ICT) and e-commerce among both consumers and small businesses.

9.2 Farm Management Information Systems Functionalities and Applications

Agriculture is a complex system that incorporates a number of interactions between farmers, advisors, traders, governmental bodies, farm machinery, environmental regulations, economic estimations and others. This system has been summarized in the form of a rich picture in Fig. 9.1 that shows apart from the interactions, the concerns and conflicts between the different entities, where the farm manager is in the middle of the proposed system (Sørensen et al. 2010).

FMIS can cover a large number of functions, such as inventory, calendar, direct sales and site-specific management functions. A set of 10 functions was presented by Fountas et al. (2015a) and is given in Table 9.1.

Apart from human-centered FMIS, there has also been a significant technological evolution in innovations of on-board tractor performance monitoring systems that enables the acquisition of tractor and implement status data through the ISOBUS (universal protocol for electronic communication between implements, tractors and computers) protocol (Tsiropoulos et al. 2013a) and provides useful information to optimize the overall operations and field productivity (Backman et al. 2013). These tractor-based systems together with accurate GPS systems emerge as standard features on contemporary tractors with the aim to provide enhanced farm and operations management through the use of extensive databases as the basis for decision support and control actions. Moreover, the development of autonomous vehicles adopted to field tasks will gradually change the role of the tractor operator toward monitoring and strategic management as this development will require an explicit

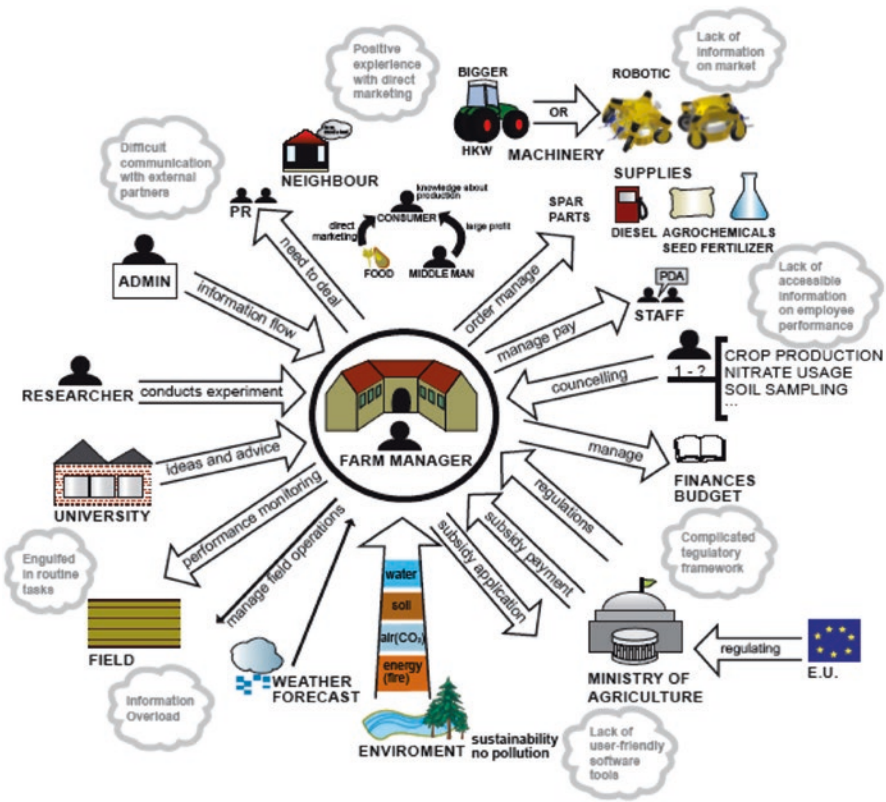

Fig. 9.1 Rich picture of a Farm Management Information System (Sørensen et al. 2010)

management information system capable of managing interactive information flows and provide useful guidelines in real-time for operations execution (Tsiropoulos et al. 2013b). The interconnection between the ISOBUS and precision agriculture innovations will meet the farm manager's demands by open up a wealth of information for improved management of crop production.

With respect to having the tractor in the middle of an information system, a shift of perspective from the farmer or farm manager as the core of the system, to a tractor-centric approach leading to an innovative FMIS architecture where the information flows derive from an intelligent machinery entity that has an upgraded role as part of the decision making process was presented by Fountas et al. (2015b). The term Farm Machinery Management Information System (FMMIS) was used to describe the above approach, which relies on information-to-action decision processes for field operations and is depicted as a rich picture in Fig. 9.2.

However, there is not always a smooth path to commercial availability even for systems that have already shown their potential in a research setting. In just one country, the Netherlands for example, several commercial initiatives to develop geo-information system (GIS) platforms for use in agriculture have failed. However,

Table 9.1 Farm Management Information Systems (Fountas et al. 2015a)

Function title	Function description
Field operations management	Recording of farm activities to help farmer optimize crop production by planning activities and observing the actual execution of planned tasks. Preventive measures may be initiated based on the monitored data.
Best practice (including yield estimation)	Production tasks and methods related to applying best practices according to agricultural standards (e.g. organic standards, integrated crop management (ICM)). A yield estimate is feasible through the comparison of actual demands and alternative possibilities, given hypothetical scenarios of best practices.
Finance	Estimation of the cost of every farm activity, input–outputs calculations, equipment charge-outs, labour requirements per unit area. Projected and actual costs are also compared and input into the final evaluation of the farm's economic viability.
Inventory	Monitoring and management of all production materials, equipment, chemicals, fertilizers, and seeding and planting materials. The quantities are adjusted according to the farmer's plans and customer orders.
Traceability	Crop recall, using an ID labelling system to control the produce of each production section, including use of inputs, employees and equipment, which can be easily archived for rapid recall.
Reporting	Creation of farming reports, such as planning and management, work progress, work sheets and instructions, orders purchases, cost reporting and plant information.
Site-specific	Mapping the features of the field, analysis of the collected data, generation of variable-rate inputs to optimize input and increase output. This is the Precision Farming Technologies component. It could be separate software or integrated.
Sales	Management of orders, charges for services and online sales.
Machinery management	Includes the details of equipment usage, the average cost per work-hour or per unit area. It also includes fleet management and logistics.
Human resource management	Employee management, availability of employees in time and space, handling work times, payment, qualifications, training, performance and expertise.

a system called "Akkerweb" (in English: Farm Maps; www.akkerweb.nl) is currently gaining credence. Akkerweb is the product of a public–private partnership between Agrifirm, the largest farmers' cooperative in The Netherlands, and Wageningen UR, the leading agricultural research organization in The Netherlands.

Akkerweb is geo-information system platform that allows geo-data acquisition, management, visualization and use at the farm level in combination with a standard FMIS (Kempenaar et al. 2016). In addition, farm advisors can access the data if the farmer wants to share data. Akkerweb offers GIS functionality and a number of general free for use applications ("apps"), such as a cropping scheme app, a satellite data app and a sensor data app to visualize and analyze soil and crop data and to generate task maps. Akkerweb also contains several subscription-based apps for variable-rate application of pesticides and fertilizers. The success of Akkerweb is due to the combination of its ICT infrastructure and its science-based content, the bottom-up development with users in the driver's seat, and the effective cooperation

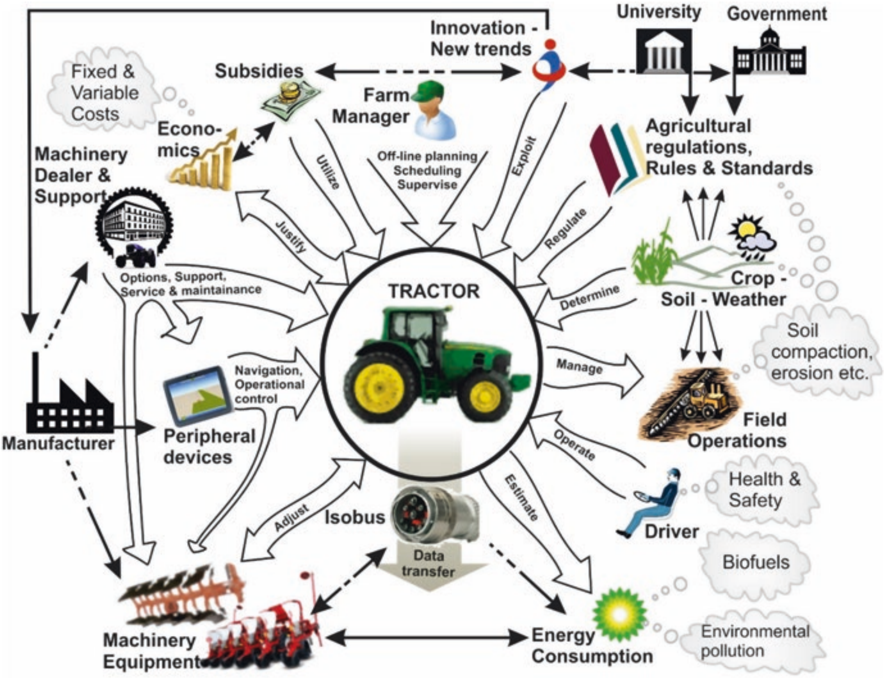

Fig. 9.2 Farm Machinery management information system (Fountas et al. 2015b)

between a farmers' cooperative, a research institute and an IT company with sufficient means to build the required infrastructure. Akkerweb is an open platform in the sense that third parties can also use the Akkerweb platform to develop and offer fee-based services. Today, data of ca. 30,000 crops are stored using Akkerweb.

There are of course many other commercial FMIS in Europe and around the world that are used by farmers or farmers' cooperatives. A successful system is the FARMSTAR in France (https://www.farmstar-conseil.fr), which is a satellite technology-based service devised and delivered by Airbus Defence and Space since 2003. FARMSTAR's users are taking advice on precision agro-management knowing the exact time and area where they should apply fertilizer and pesticides. Satellites flying over the fields take accurate measurements of the radiant solar energy absorbed and reflected from the surface across the farm terrain. The value of the reflected energy varies according to the level of growth of the vegetation, thus satellite measurements can indicate crucial field factors such as soil moisture, surface temperature, leaf cover and level of chlorophyll. Personalized "recommendation cards" divided into very small areas of the field are provided to each user, offering her or him prescriptions for the necessary amounts of chemicals that should be applied, as well as where and when to be applied. The FARMSTAR service provides its subscribers with the opportunity for a better environmental, economic and social management.

9.3 Costing Functionalities of FMIS

One of the main advantages of precision agriculture technologies is to make cost savings in crop production, related to the use of more effective techniques or to reduce the quantity of resources (e.g. water, fertiliser, crop protection) for a range of activities. This advantage has been acknowledged at the level of a single technique to highlight the positive effects of its introduction, but the benefits on the whole farm have received less attention. How a farm might benefit from the use of precision agriculture techniques still remains an open question, given the high initial investment and the level of education and training required. The introduction of evolved FMIS could be seen as a possible answer because they can collect and archive data on the use of resources and elaborate information on final product costing. Moreover, they can provide a more comprehensive picture of the cost of using precision agriculture technologies, evaluating other aspects of the costs of precision agriculture technologies such as the effect of the investment on the final cost of agri-food products.

To support a solid costing functionality, FMIS need a quite sophisticated cost management structure based on three processes (Carli and Canavari 2013): data collection, elaboration of information and decision making. The data collection process is related to these elements depicted in Fig. 9.3: (1) the time spent by human resources on crops, (2) the time spent by machines (e.g. tractor) or equipment (e.g. a precision agriculture device) on each crop, (3) the use of external services in terms of costs and time and (4) the quantity of resource distributed on each crop, in a specific time and position.

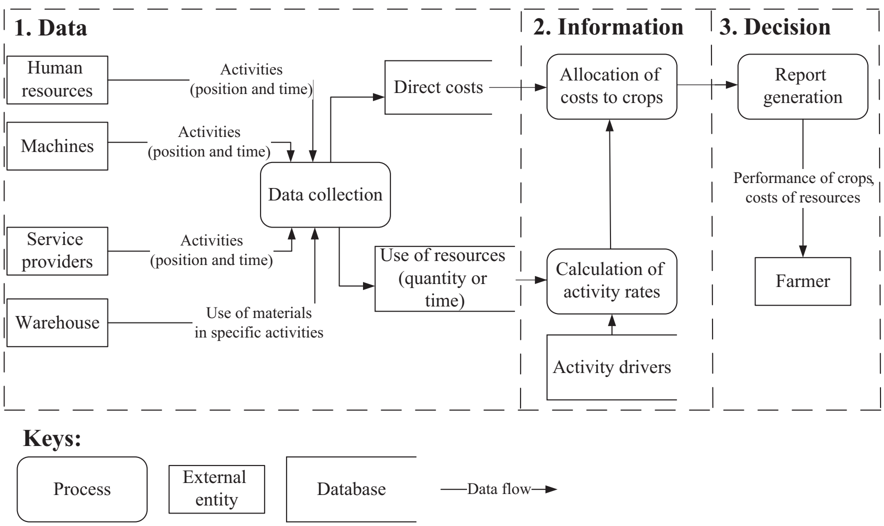

Fig. 9.3 Data Flow Diagram of the cost allocation on crops

In the data collection process, different levels of accuracy can be reached, according to the technological support available. For instance, the use of fertilizer on a crop can be measured as a single value for the whole field without any kind of instrument, or it can be measured more accurately using precision agriculture technology and then drawing a map of its distribution on the field. In this case, the data structure of the FMIS must be designed to track this information as we will discuss later.

The elaboration of cost information aims to provide decision makers such as farmers, technicians, agronomists, with the necessary information on profitability of crops. Decisions on crop production should consider their profitability, but, as anticipated, it reveals that it is particularly complex to collect and elaborate data on costs. Conversely, data on revenues are more accessible because they are based on the market prices of agri-food products or are defined by contractual agreements.

The elaboration phase of cost data can be based on two different models which can be combined together: direct costing and activity-based costing. As an accounting practice, direct costing charges variable costs directly to products (Siegel and Shim 2000). In the case of agricultural practice, this is possible if we charge the direct costs to the activity performed on the specific crop and field. For instance, in a fertilizing activity, the cost of crop protection should be allocated to an activity related to a particular crop (e.g. the second distribution of crop protection on potatoes on field number 2). Although it is quite simple to model an information system to record this type of information, it is far more complicated to record this information from the field, especially when the same activity is carried out on different fields in sequence: for instance, the specific quantity spread on each crop should be recorded. In this case, precision agriculture technologies can provide two types of useful information: (1) the position of the machine or human resource and (2) the quantity of time spent or of resource used. Combining these data, it is possible to adopt a direct costing approach.

If these data are not available, the use of activity-based costing procedures becomes a possible alternative. Activity-based costing methodology has been developed because of the increase in fixed cost share among the total costs of an industrial company (Cooper and Kaplan 1988; Johnson and Kaplan 1987). Its core principle is to allocate fixed costs according to a precise measurement of resource use. First, through the Resource-Activity Assignment Process, the resource consumption generated by the different activities performed in a company is measured; then the Activity-Cost Object Tracing Process finds out which activities are required by products (or final cost objects) and allocates the corresponding portion of costs (Ferreira 2004). The purpose of this paragraph is not to introduce activity-based costing, however, we present a simple example to clarify its logic. Typically, the fixed costs of a tractor could be allocated to crops according to their use. Nevertheless, in the case of a farm with a crop cultivated on a large extension with limited demand for activities involving the tractor, and a crop cultivated on a smaller extension requiring an intense use of the tractor, a classical cost allocation model based on the extension could to be misleading. The large crop would receive the majority of the fixed cost, although it generated a minimal use of the resource, whereas the crop cultivated in the smaller extension would appear to require less resource that it actually did. Although formally correct from an accounting point of view, this procedure could induce an incorrect interpretation on the profitability of the two crops by allocating the majority of the costs to the product with the smaller demand on the activity generating the costs. Conversely, an activity-based procedure for cost allocation could make use of the time spent by the tractor on the two crops. This allocation of cost is able to measure the use of the resource better without producing a significant change in the reality, favouring a consistent process of decision making. To be applied, it is necessary to record the time spent by the tractor on each crop, and then divide its indirect costs (e.g. maintenance, depreciation) according to that time.

The application of precision agriculture technologies could favour the accuracy of the measurement of cost drivers that can be used for activity-based cost allocation. For instance, positioning and mapping solutions could be employed to track human resources, machines and equipment in their movements in the fields. Variable-rate of application systems can record the quantities of material distributed across the field. These two sets of data (position and time spent, and position and quantity of material distributed) could be used as an activity driver to allocate other fixed costs such as depreciation.

Table 9.2 reports a possible solution for cost allocation on final products. In some cases, both the procedures, direct and activity-based are possible and the availability of data determines which is feasible. The time used by machines and human resources can be regarded as the most accessible cost factor as suggested by Kaplan and Anderson (2007).

From this example, the pivotal role of FMIS emerges in supporting the elucidation? of cost data supporting direct costing and activity based costing procedures, and incorporating a reporting functionality dedicated to product costing.

The structure of the FMIS database could be modelled around the entities of fields, crops and activities (Carli and Canavari 2013; Carli et al. 2014). The combination of these elements favour the definition of simple and solid cost allocation procedures. Nevertheless, the advent of precision agriculture technologies can require deep changes in this model: the level of detail reachable with positioning technologies goes far beyond the single field and crop. It is now possible to verify when a machine or a human resource is employed on a specific sub-area of a field or even on a particular tree. This technological evolution enables an even more accurate costing model: for instance, in orchards, the single trees can be considered cost objects, and can be compared in terms of costs and yields (Tsiropoulos and Fountas 2015). This open a new perspective on the modelling of FMIS and the definition of their costing functionality.

Table 9.2 Solutions for cost allocation on final products

Type of resource	Example	Cost	Possibility to apply direct costing and data required	Activity-based costing	Examples of measurement systems
Machine	Tractor	Fuel consumption	Fuel used on a single crop (e.g. level control)	Time spent on each crop	GPS
		Fixed costs incl.: Depreciation	Not applicable		
		Maintenance	Not applicable		
Human resources	Farmer or seasonal worker	Cost per hour	Time spent on a single crop (GPS positioning)	Time spent by human controlled machines on each crop	GPS on machine
Material	Crop protection	Cost of the input	Quantity distributed on each crop (position and quantity from GPS and ISO-BUS)	Time spent by machines on each crop	GPS on machine
	Fertiliser				
	Lime				
	Seeds				
	Water				
External service	Specific crop service (e.g. pruning)	Cost of the service per field	Time spent by external supplier on each crop	Not applicable	Not applicable
	General service (e.g. consulting)	Cost of the service per field	Not applicable	Time spent by human resources or machine son the crop	GPS data

9.4 Adoption of FMIS

The adoption process of technological innovations in agriculture is highly complex because it is affected by a broad range of factors and drivers that could affect the decision to adopt or reject the innovation. Behavioural attitudes, education and awareness, cultural background and norms, social influences, economic and financial variables, policy and market conditions can act as explanatory variables for the adoption patterns of innovation, together with structural and infrastructure factors, availability of support, the characteristics of the innovation itself (Daberkow and McBride 2003; Howley et al. 2012). Examples from literature have proved that the interaction between potential adopters and technologies to be evaluated for adoption must be considered strongly context-specific.

Literature provides examples of models to analyze the set of factors affecting the decision to adopt or reject technological innovations. The Technology Acceptance Model (TAM) (Davis 1989) is widely used in the analysis of the determinants of technology adoption. Focusing on attitude and perception aspects, the model identifies two main constructs (Perceived Usefulness and Perceived Ease of Use) as predictors of the final intention to adopt a technological innovation (User Acceptance). The TAM has been developed further and integrated with constructs from other theoretical models (Venkatesh et al. 2003; Awa et al. 2012). Subsequent adaptations of TAM aimed at identifying the most relevant factors to detect the intention to adopt ICT innovations, both in IT and in the agricultural field (Davis and Venkatesh 2004; Adrian et al. 2005) and tried to validate additional constructs and items to be considered as drivers of the decision process of new technology adoption.

It must be noted, that the strength of factors and drivers affecting farmers' behaviour and their decision to adopt or reject technological innovations depend strongly on many aspects: socio-demographic features of farmers, cultural and social background, characteristics of farms, farming types, type and features of the technology evaluated (e.g. compatibility, costs, profitability, resources savings); external environment (e.g. infrastructure, support from third parties, availability of advisory services, experiences from early adopters, governmental approach, market, financial situation) (Alvarez and Nuthall 2006; Lu et al. 2014; Pierpaoli et al. 2013; Pedersen et al. 2004; Lawson et al. 2011). The relationship between farmers and technologies (e.g. time spent in getting used to the technologies, farmers' dependence on specific solutions and farmers' involvement in the development of new applications) could play a relevant role also in the adoption or rejection choice of technological innovations (Pedersen et al. 2004; Lawson et al. 2011). Finally, requests from stakeholders and actors in the agricultural supply chain (such as traceability or demonstration of environmental sustainability) can exert an influence on farmers' behaviour and decisions (Pedersen et al. 2004).

The use of FMIS in agriculture has been investigated in depth during the last few years because the adoption of management systems to collect and analyze data from in-field activities has become strategically mandatory to support decision-making processes and gain efficiency. The advent of precision agriculture and related technologies provided farmers with large amounts of available data to be processed (Zhang et al. 2002); therefore, information flows and their management, and the consequent support to decision-making are the very critical issues that FMIS must cope with (Sørensen et al. 2010; Fountas et al. 2015a, b).

Many examples of FMIS models can be found in the literature, as outlined in Fountas et al. (2015a, b). During recent years, the development of FMIS has led to the incorporation of more sophisticated functionalities, with the aim of increasing FMIS compatibility with existing technologies, their capability of collecting and processing data, their effectiveness in supporting decision-making. Nevertheless, contributions in the literature have highlighted that their adoption is affected or can be conditioned by some critical factors. Nikkilä et al. (2010) pointed out that usability, reliability, availability, resources saving, convenience, ease of use and connectivity are critical features for end-users when evaluating FMIS. On the other hand, unintuitive or excessively complicated systems, or extremely wide sets of features provided by FMIS could cause misuse and be responsible for low levels of adoption (Nikkilä et al. 2010). Murakami et al. (2007) provided a list of requirements that information systems should possess to support precision agriculture technologies such as integration with existing systems, interoperability with other software packages and data sources, scalability and accessibility. In Sørensen et al. (2010), the interoperability and the transfer of information between systems are mentioned as significant issues to be improved in future FMIS, with the aim of meeting farmers' needs in terms of FMIS functionalities and interfaces. The difficulty in assessing the intangible benefits of information system improvements, and the influence of farmers' computer readiness on the perception about the value of information systems must be included among the critical factors affecting the adoption of FMIS (Alvarez and Nuthall 2006). In addition, other factors such as socio-demographic features of farmers, software fitting and matching with existing systems, ease of use, time and money saving can influence potential users' decisions to adopt FMIS (Alvarez and Nuthall 2006). Similarly, compatibility between hardware and software, adaptability, flexibility, reduction of training needs, and provision of useful and ready-to-use information outputs must be included among the features that FMIS should have to enhance their diffusion (Fountas et al. 2015a, b). Although returns from FMIS adoption in terms of better data management and support to decision making could not be easily quantified by end-users, benefits of the introduction of FMIS should be clearly identifiable and measurable in terms of key performance indicators (Fountas et al. 2015a, b).

Evidence from the literature confirms that advancements and improvements in FMIS design and modelling cannot overlook the interaction with farm stakeholders (Nikkilä et al. 2010), the identification of the scope of a system, boundaries, processes and actors asking for specific requirements of the systems (Sørensen et al. 2010). In the light of these premises, it follows that exploration of the most pertinent factors that affect the intention to adopt FMIS must be deepened, together with a careful evaluation of context-specific variables that could affect farmers' behaviour and perceptions.

Methodologies to estimate FMIS adoption: preliminary exploration of attitudes and beliefs – evidence from the ROBOFARM Project

A study focusing on the identification of the most relevant factors affecting the decision to adopt ICT innovations, and on the steps of this decision process was carried out during the ROBOFARM Project (ICT-AGRI ERA-NET Project "Integrated robotic and software platform as support system for farm level business decisions", funded under the European Union Seventh Framework Programme for Research, Technological Development and Demonstration Activities). This 2-year project aimed to create a demonstrator platform that integrates existing software and hardware technologies into a single system making use of robots with sensors and communication systems to collect data from the field, to be conveyed to and managed by a Farm Management Information System (FMIS).

During the project, a preliminary qualitative analysis was done to understand the attitude of farmers towards ICT innovations and evaluate the adoption of new software solutions for farm information management, together with the relevant steps of the decision process and the intervening factors. Qualitative explorative approaches are usually suggested to conduct in-depth investigations on relatively under-explored topics, trying to identify underlying or latent interactions between factors. Targeting small groups of participants, these methods rely on interviews and focus groups to help in pinpointing the most relevant features of a phenomenon, allowing the identification of significant issues that derive from interviewees' experiences. In the ROBOFARM Project, the focus group discussion method was selected because the fundamental assumption underlying this approach is that opinions, preferences and behaviour emerge from the interaction among informants into a shared context re-created through the focus group setting. Even though focus groups showed some limitations, they enable large amounts of qualitative evidence to be collected, and favour the emergence of experiences and themes (Hines 2000). In particular, they control the interactions and synergy among participants to deepen the investigation of complex behaviour and motivation because the discussion between interviewees provides valuable insight about the extent of consensus and divergence among the group (Morgan 1996).

Six focus groups were established during the summer of 2013 in three countries involved in the project, Greece, Italy and Turkey. A maximum of 10 participants per focus group (recruited among farmers and technicians) were invited to discuss selected topics according to a specific semi-structured protocol aimed at stimulating their interaction. Main topics and objectives of the sections of the qualitative schedule are shown in Table 9.3.

The main objectives of the focus groups were:

– To identify the main factors affecting the decision to adopt a technological innovation (new FMIS);
– To list the steps leading to the adoption of a technological innovation;
– To identify the links between the steps of the process of adoption and the factors that could influence each single step.

Table 9.3 Qualitative schedule of the focus group

Topics (sections)	Objectives
A. Organizational and professional tenure	Role of socio-demographic features (income, company size, years on business, land and equipment ownership, role of the interviewee, age, education) in influencing the adoption of technological innovations
B. Technology adoption in agriculture	Attitudes, opinions and experiences regarding the adoption of technological innovations
C. ICT/technological innovations' adoption process	Identification of the steps that lead to the adoption (or rejection) of technological innovations; identification of the factors (intrinsic and extrinsic) affecting each step of the adoption process
D. Opportunities and limitations	Identification of positive and negative aspects regarding the adoption of technological innovations (benefits, drivers to be enhanced or adjusted, what's missing)

Source: authors' elaboration from (Pignatti et al. 2015)

Results are shown in Table 9.4, which provides a summarized overview on the outcomes of the focus group discussions. A detailed description of the results and main outcomes can be found in (Pignatti et al. 2015).

Interviewees agreed upon a "six-steps" decision process for the adoption of information management technologies in agriculture:

- 1. Identification of needs
- 2. Evaluation of available solutions
- 3. Analysis of scenarios (comparisons of solutions and investments)
- 4. Risks and Benefits analysis and Return on Investments
- 5. Adoption
- 6. Evaluation after use.

Three main groups of factors influencing the adoption decision process were identified during the focus groups.

A. Features of farms and farmers

According to the interviewees, structural features of the farms (e.g. size, income), socio-demographic traits of farmers (age, education) and farmers' perceptions and orientations toward innovation and entrepreneurship are particularly relevant in the first steps of the decision process regarding the adoption of technological innovations, since they can affect the identification of the needs and the evaluation of the available solutions. Then, in the subsequent stages of the decision process (before adoption), additional farmers' features (such as awareness, knowledge gaps, anxiety, uncertainties, familiarity with innovations) were mentioned as particularly influential, as they seem to become relevant when risks/benefits analyses are performed. In these advanced stages of the decision process, economical characteristics of the farms and their development perspectives (both in terms of business and Return of Investment (ROI)) play an important role, because the introduction of new systems for data collection and information management can require significant organizational changes and investments. Availability and provision of training were also mentioned as important factors affecting the decision about adopting innovations: training is fundamental to fill knowledge and experience gaps. Nonetheless it could absorb considerable financial resources and reduce labor hours. Therefore its role in the decision process becomes fundamental especially in the last steps of the process and after the adoption. In fact, being perceived as an investment, training must be available as soon as the innovation is adopted, to make farmers familiar with the new technologies and avoid misuse, inefficiency and rejection.

B. Features of technological innovations

Focus group discussions highlighted the influence of this group of factors on all the steps of the decision process regarding the adoption of new FMIS. In the first stages of the decision process when available solutions are considered, innovations seem to be evaluated according to their "functional" features (such as usability, ease of use, functions, flexibility, reliability). Usefulness was considered by participants as a fundamental feature for ICT innovations during all the stages of the adoption

Table 9.4 Summary of the outcomes of the focus group discussion

		Factors		
		A. Features of farms and farmers	B. Features of technological innovations	C. Features of external environment
Adoption steps	1. Identification of needs	Age	Complexity of needs (short term vs. long term solutions) and of technologies under evaluation	Future growth perspectives
		Education and culture	Type of technology and profitability	Voluntariness/ legislation
		Propensity		External/third parties' influence (consultants, technicians, associations)
		Open-mindedness		
		Entrepreneurial orientation		
		Planning orientation		
		Company's size		
		Production type		
		Income/economic status		
	2. Evaluation of available solutions	Age	Ease of use	Third parties' participation to innovations
			Usefulness	
		Open-mindedness	Reliability	Word of mouth and experience sharing (early adopters)
		Perception of risks	Usability	External/third parties' support
		Company's size	Functionality/ identifiable performances	
			Flexibility	
			Path dependence from the adopted innovation	
	3. Analysis of scenarios (comparison of solutions and investments)	Anxiety/fear	Usefulness	External/third parties' support
		Awareness raising	Observability of performances	
		Training	Effectiveness	
		Initial investments	Complexity	
		Company's perspectives	Degree of fit and compatibility	
			Trials and tests on the field	
			Perception of costs/ benefits	

(continued)

Table 9.4 (continued)

	Factors		
	A. Features of farms and farmers	B. Features of technological innovations	C. Features of external environment
4. Risks/benefits analysis and return on investments	Age	Usefulness	External/third parties' support
	Education	Effectiveness	Financial support
	Anxiety/fear	Perception of costs/benefits	Policies/legislation
	Familiarity with innovations	Profitability	
	Income/economic status	Price/performance ratio	
	Production type	Path dependence from the adopted innovation	
	Costs and benefits/ROI		
5. ADOPTION	–	–	–
6. Evaluation after use	Training	Performance	External/third parties' support
		Trials and tests on the field	
		Compatibility	
		Usability	

Source: authors' elaboration from (Pignatti et al. 2015)

process; path dependence from innovations was also mentioned as critical both in the initial and in the latter stages of the decision process, since it could be a constraining factor. When economical evaluations and comparisons become a relevant part of the decision process, additional factors such as effectiveness of the innovation, complexity, degree of fit and compatibility with existing systems, observability of performances, perceived costs and benefits, profitability, and price/performance ratio are taken into consideration. Return on Investments is a pivotal variable that many interviewees mentioned. Insofar as technological innovations might be viable and useful, their evaluation and adoption depends also on their profitability, on investments needed, and on farmers' exposure to risks.

Finally, the fundamental role of trials, field tests, and successful adoption experiences was acknowledged by all the interviewees: in-field demonstrations and cases of pilot farms seem to be a powerful driver to promote the adoption of a technological innovation, and to favor its diffusion among end-users.

C. Features of the external environment

A strong influence of the external environment on adopting technological innovations was acknowledged by interviewees, affecting all the steps of the decision process. Market environment, agricultural policies and legislation, and funding policies define the context in which farmers elaborate on their decision, and exert an unquestionable influence on all the stages of the adoption process. Stakeholders of different nature can orient the decision of adoption and could even force the adoption of specific technological innovations through legislative obligations, or could boost it through supporting measures and economic stimuli. Alternatively they could discourage it controlling different facilitating conditions, such as "innovation-friendly" policy orientations, public funding, and financial support against market risks.

The technological framework surrounding an innovation plays a relevant role: the provision of up-to-date and easy-to-use solutions, along with new approaches for their dissemination (e.g. shareware, open source tools) could promote a faster diffusion of new ICTs, thanks to the reduction of required financial effort and to the availability of affordable solutions.

Word of mouth, sharing of experiences, and contacts with early adopters were listed by participants as influential factors when deciding on the adoption of new FMIS, especially in the first stages of the decision process. Information by pilot farmers, successful or negative experiences of early adopters, and the chance to evaluate concrete results and performances of the innovations seem to be a more reliable reference system for farmers to trust, and to consider when evaluating adoption.

Informants mentioned external support, as a pivotal factor affecting the decision to adopt: qualified external support from technicians, consultants and associations is sought both when available solutions are evaluated, and when the final risks/benefits analysis is performed, since experts' knowledge and experience can increase farmers' awareness and trust toward innovations. External third parties' support can bridge farmers' knowledge gap regarding potential usefulness and profitability of innovations, and enhance their confidence thought demonstrations and trials. Moreover, the involvement of external trusted third parties (such as governments, research institutes, associations) in the development of technological innovations seems to act as a guarantee of reliability of the innovation itself, and increases the likelihood of adopting.

As a conclusion, the results of the focus group discussions of the ROBOFARM project confirmed the importance of well-known factors as influential drivers in the decision process regarding the adoption of new FMIS. Focusing on a specific innovation (new software), some of the factors mentioned in literature were stressed more than others, and some cues for further discussions were provided. The attempt to define the steps of the decision process regarding the adoption of technological innovation and to identify the most relevant drivers affecting each step can be considered a valid suggestion to set up further studies in this area. New research efforts could specify in more detail the crucial steps of the process towards the final decision, and the pertinent factors with the final aim of defining a model of adoption process valid for agribusinesses and able to fill the gaps faced by farmers in assessing new technologies (e.g. knowledge gaps, communication problems, lack of financial support).

The outcomes of the focus group discussions clearly pinpointed that the dynamics underlying the adoption processes of technological innovations are markedly country-specific, "context"-specific, site-specific, technology-specific and farmer-specific. Given this extreme dependency on the context, we advocate further analyses to measure the relative importance of the relevant factors affecting the adoption of technological innovations, and the relations among them (e.g. moderation, mediation) building a theory of adoption specific for the agricultural practice.

9.5 Discussion and Conclusions

A wide range of technologies and tools have become available for capturing, storage, analysis, wireless transmission, visualization, use and sharing of digital data and information in recent years. Several of these technologies are integrated in platforms that facilitate digital data and information use. In addition, farmers collect the data from their daily activities and field operations either through online sensors or manually and in most of the cases at paper format. The necessity to register all activities, as inputs and outputs for farm activities has been enforced by the Cross Compliance requirements by the European Commission. There are a number of software solutions to register these data at farm office, but the ability to gather precise application data at field level does not exist, especially when it is referred to use application of fertilizers and pesticides using modern tractor and implements. This role is expected to be covered by mobile devices that have started to replace computers and in the near future these mobile devices would be the main computational devices for most of computer users. With each passing season, another wave of mobile devices is released, which will be more powerful than the generation preceding it. Mobile devices of today have the necessary processing power, hardware and capabilities for being able to be used efficiently for automated data gathering in the field.

In a recent study on FMIS functions, Fountas et al. (2015a) reviewed 141 commercial FMIS from Europe, North America, and Australia. After defining 11 functionalities that an FMIS can support (see Table 9.1) and verifying their presence in the sample of commercial systems, a cluster analysis was conducted to identify homogenous groups of systems. The cluster analysis revealed four clusters named according to their main features. One of the clusters presented a higher level of complexity supporting functions weakly represented in the systems of the other three clusters. The reason could be that these high level functions–traceability, best-practice estimate, and quality assurance–require the integration of data from different sources (e.g. field and operations, machines, HR). Therefore, they can be deployed only when the overall system reaches a certain level of completeness and complexity.

Two dimensions were identified as the thresholds towards two possible pathways of development of more sophisticated systems. Inventory management makes possible to develop traceability and quality assurance. Site specific functions support the inclusion of decision making functionalities. Future FMIS should go in the direction of combining site specific and inventory management functions in order to collect enough data to convey a reliable support decision making process and solid traceability and quality assurance functions.

Earlier in this chapter, we introduced the FarmBO system as an example of how data from different sources (e.g. machines, HR) can be collected using precision agriculture technologies and generate insights for decision making on costs based on data directly collected on the field (Carli et al. 2014). The availability of site specific functions can favour the collection of more accurate data on costs and the development of more precise analyses on crop costing and profitability.

We envision a promising way for the development of FMIS in the integration of site specific functions into a sophisticated decision making environment, where farmers and technicians are provided with reports to improve their choices and increase the yields of their crops. This would be possible only if data from sensors are processed with well-established cost management approaches adapted to the specificities of the agricultural practice. For instance, since site-specific solutions applied to orchards may offer data on the single trees very soon, the amount of crop protection would be decided and measured for each single tree. The integration of precision agriculture solutions and the decision support module of a FMIS can pave the way to a more fine grained accounting process till the level of the single tree. New research efforts could be dedicated to the definition of a straightforward stepwise process to elaborate the rich and complex data from sensors. Therefore, the decision support module of the FMIS would be able to provide farmers with just the relevant data for each activity and choice to make. A challenge for future FMIS is in this meso-level of data elaboration: only the systems able to *make sense* of the richness of the data provided by sensors and *advise* the farmer on possible options will differentiate in the competitive arena.

References

Adrian AM, Norwood SH, Mask PL (2005) Producers' perceptions and attitudes toward precision agriculture technologies. Comput Electron Agric 48(3):256–271

Alvarez J, Nuthall P (2006) Adoption of computer based information systems: The case of dairy farmers in Canterbury, NZ, and Florida, Uruguay. Comput Electron Agric 50(1):48–60

Awa HO, Ojiabo OU, Emecheta BC (2012) Integrating TAM and TOE frameworks and expanding their characteristic constructs for E-commerce adoption by SMEs. In: Proceedings of Informing Science & IT Education conference (InSITE) 2012 (12:571–588). Informing Science Institute

Backman J, Oksanen T, Visala A (2013) Applicability of the ISO 11783 network in a distributed combined guidance system for agricultural machines Original Research Article. Biosyst Eng 114(3):306–317

Boehlje MD, Eidman VR (1984) Farm management. Wiley, New York, p 806

Carli G, Canavari M (2013) Introducing direct costing and activity based costing in a farm management system: a conceptual model. Procedia Technol 8:397–405

Carli G, Canavari M, Grandi A (2014) Introducing activity-based costing in farm management. Int J Agric Environ Inf Syst 5(4):69–84

Cooper R, Kaplan RS (1988) Measure costs right: make the right decisions. Harv Bus Rev 66(5):96–103

Daberkow SG, McBride WD (2003) Farm and operator characteristics affecting the awareness and Adoption of precision agriculture technologies in the US. Precis Agric 4(2):163–177

Davis FD (1989) Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Q 13(3):319–340

Davis FD, Venkatesh V (2004) Toward preprototype user acceptance testing of new information systems: implications for software project management. IEEE Trans Eng Manag 51(1):31–46

Ferreira WN (2004) Is activity based costing a blockbuster? extension economic reports. Clemson University, Clemson

Fountas S, Ess D, Sorensen CG, Hawkins S, Blumhoff G, Blackmore S, Lowenberg-DeBoer J (2005) Farmer experience with precision agriculture in Denmark and the US eastern corn belt. Precis Agric 6:121–141

Fountas S, Wulfsohn D, Blackmore S, Jacobsen HL, Pedersen SM (2006) A model of decision making and information flows for information-intensive agriculture. Agric Syst 87:192–210

Fountas S, Carli C, Sørensen CG, Tsiropoulos Z, Cavalaris C, Vatsanidou A, Liakos B, Canavari M, Wiebensohn J, Tisserye B (2015a) Farm management information systems: current situation and future perspectives. Comput Electron Agric 115:40–50
Fountas S, Sorensen CG, Tsiropoulos Z, Cavalaris C, Liakos V, Gemtos T (2015b) Farm machinery management information system. Comput Electron Agric 110:131–138
Gladwin H (1989) Ethnographic decision tree modelling. Sage Publications Ltd., London
Hines T (2000) An evaluation of two qualitative methods (focus group interviews and cognitive maps) for conducting research into entrepreneurial decision making. Qual Mark Res Int J 3(1):7–16
Howley P, Donoghue CO, Heanue K (2012) Factors affecting farmers' adoption of agricultural innovations: a panel data analysis of the use of artificial insemination among dairy farmers in Ireland. J Agric Sci 4(6):171
Johnson HT, Kaplan RS (1987) Relevance lost: the rise and fall of management accounting. Harvard Business Press, Boston
Kaplan RS, Anderson SR (2007) Time-driven activity-based costing: a simpler and more powerful path to higher profits. Harvard Business Press, Boston
Kempenaar C, van Evert FK, Been T, Kocks CG, Westerduk CE (2016) Towards data-intensive, more sustainable farming: advances in predicting crop growth and use of variable rate technology in arable crops in the Netherlands. ICPA, St. Louis
Lawson LG, Pedersen SM, Sørensen CG, Pesonen L, Fountas S, Werner A, Oudshoorn FW, Herold L, Chatzinikos T, Kirketerp IM, Blackmore S (2011) A four nation survey of farm information management and advanced farming systems: a descriptive analysis of survey responses. Comput Electron Agric 77:7–20
Lewis T (1998) Evolution of farm management information systems. Comput Electron Agric 19:233–248
Lu Y, Lu Y, Wang B, Pan Z, Qin H (2014) Acceptance of government-sponsored agricultural information systems in China: the role of government social power. IseB 13(2):329–354
Magne MA, Cerf M, Ingrand S (2010) A conceptual model of farmers' informational activity: a tool for improved support of livestock farming management. Animal 4:842–852
Morgan DL (1996) Focus groups. Annu Rev Sociol 22:129–152
Murakami E, Saraiva AM, Ribeiro Junior LCM, Cugnasca CE, Hirakawa AR, Correa PLP (2007) An infrastructure for the development of distributed service-oriented information systems for precision agriculture. Comput Electron Agric 58(1):37–48
Nikkila R, Seilonen I, Koskinenet K (2010) Software architecture for farm management information systems in precision agriculture. Comput Electron Agric 70(2):328–336
Pedersen SM, Fountas S, Blackmore BS, Gylling M, Pedersen JL (2004) Adoption and perspectives of precision farming in Denmark. Acta Agric Scand Sect B – Soil Plant Sci 54(1):2–8
Pierpaoli E, Carli G, Pignatti E, Canavari M (2013) Drivers of precision agriculture technologies adoption: a literature review. Procedia Technol 8:61–69
Pignatti E, Carli G, Canavari M (2015) What really matters? a qualitative analysis on the adoption of innovations in agriculture. J Agric Inf 6(4):73–84
Sørensen GC, Fountas S, Nash E, Pesonen L, Bochtis D, Pedersen SM, Basso B, Blackmore SB (2010) Conceptual model of a future farm management information system. Comput Electron Agric 72:37–47
Siegel JG, Shim JK (2000) Accounting handbook. Barron's Educational Series, Hauppauge
Tsiropoulos Z, Fountas S (2015) Farm management information system for fruit orchards. Precis Agric 15:217–232
Tsiropoulos Z, Fountas S, Gemtos T, Gravalos I, Paraforos D (2013a) Management information system for spatial analysis of tractor-implement draft forces. Precis Agric 13:349–356
Tsiropoulos Z, Fountas S, Liakos V, Tekin B, Aygun T, Blackmore S (2013b) Web-based farm management information system for agricultural robots. EFITA-WCCA-CIGR Turin, Italy
Venkatesh V, Morris MG, Davis GB, Davis FD (2003) User acceptance of information technology: toward a unified view. MIS Q 27(3):425–478
Zhang N, Wang M, Wang N (2002) Precision agriculture—a worldwide overview. Comput Electron Agric 36(2–3):113–132