Toward a New Model of Farm Management Information Systems combining ICT, Activity Based Costing, and What-If Analysis

Giacomo Carli[1], Maurizio Canavari[1]
[1]Department of Agricultural Sciences, University of Bologna
Viale Fanin 50, Bologna, Italy
giacomo.carli@unibo.it, maurizio.canavari@unibo.it

1. ABSTRACT

We present the model of a new information system for agribusiness management that supports Direct Costing and Activity Based Costing analyses. It has three main elements of novelty in comparison with existing systems. First, it collects real cost data making use of specific technological solutions. Second, it adopts Direct Costing and Activity Based Costing approaches to elaborate cost data. Third, it presents a structured section of reports, including what-if analyses, to support farm management decisions. We designed the model evaluating user needs through different round of interviews. The model aims at identifying the information requirements for the introduction of structured cost management approaches in Farm Management Information System development and depicts a viable design of the system supported by a working prototype and a set of reports for farm decision makers.

Keywords: Farm management information systems, ICT, Activity-Based Costing, what-if analysis, Italy

2. INTRODUCTION

Farm Management Information Systems (FMIS) are the subject of growing attention in research, since they can benefit from recent technological developments in terms of new Web-based services and Precision Agriculture (PA) technologies (Nikkilä, Seilonen, & Koskinen, 2010). Nevertheless, most of the interest is focused on interfaces between FMIS and machines, operators, and PA devices. The issue of how the large amount of data resulting from the above mentioned sources is processed to support farm management is usually overlooked (Sørensen et al., 2010a). Especially cost analyses is not particularly developed, yet. This is a relevant gap, since costs are central elements in managerial decisions and the allocation of general costs to products impacts future choices. In order to contribute to fill this gap, we propose a model of a FMIS that is based on modern approaches to manage costs in farm businesses: Direct Costing (DC) and Activity-based Costing (ABC) approaches.
In the next sections, we review relevant literature about FMIS, as well as about DC, and ABC approaches. Then, we describe the method applied in defining the model with the

Giacomo Carli, Maurizio Canavari. Toward a New Model of Farm Management Information Systems combining ICT, Activity Based Costing, and What-If Analysis. EFITA-WCCA-CIGR Conference “Sustainable Agriculture through ICT Innovation”, Turin, Italy, 24-27 June 2013.

support of key-informants from agribusiness. Finally, we summarize the results of this design process, illustrating the system with diagrams highlighting data structure and data flows.

3. RELATED RESEARCH AND OPEN ISSUES

Research about FMIS raised a growing interest in the last years, because agricultural activities have become more and more complex and decision-making activities need to be supported by a larger amount of information. Till now, many famers were used to carrying out analytical activities by hand, but the information processing load has become more and more intensive (Sørensen et al., 2010a). The advent of Precision Agriculture (PA) increased the need to analyze sparse information of different type and from different sources. As a consequence, the management of information and decision making are core issues in developing successful PA applications (Sørensen et al., 2010b). Research about FMIS has developed a rich strand of the literature to address the data management issues of modern agriculture and PA applications: we briefly review the core findings in Section 3.1. Then, in Section 3.2, we focus on the specific application of modern approaches to cost management in agriculture, that is Direct Costing and Activity-based Costing, depicting the questions that appear to be still open in research and how this study may contribute to make a step forward.

3.1 FMIS development

Many research efforts have been spent in putting FMIS into a clear framework, because that class of systems must addresses the specific attributes of farms: presence of biological processes, fixed supply of land, small company size, climate/weather dependency and market conditions close to perfect competition (Kay, Edwards, & Duffy, 2011; Sørensen et al., 2010b). In this context, substantial improvements have been made in terms of machinery performance monitoring, collection of site specific data (Fountas, Wulfsohn, Blackmore, Jacobsen, & Pedersen, 2006), but there is a relevant gap "between the acquiring of such data and the efficient use of in agricultural management decision making" (Sørensen et al., 2010a). Special attention has been devoted in defining the information flows with detailed data-flow-diagrams (Fountas et al., 2006), data streams related to different processes (Nash, Dreger, Schwarz, Bill, & Werner, 2009), architectural designs for the information systems (Nikkilä et al., 2010; Voulodimos, Patrikakis, Sideridis, Ntafis, & Xylouri, 2010), conceptual models and functional requirements for future FMISs (Sørensen et al., 2010a, 2010b; Sørensen, Pesonen, Bochtis, Vougioukas, & Suomi, 2011).
In this rich context, in this paper we focus on data processing aimed at supporting decision making with specific cost analysis approaches. Many information flows can become the roots for specific cost analyses and support a more conscious decision making process. The development of a specific model for a FMIS oriented to support economic decisions is a particularly relevant area of investigation, because of a growing interest in increasing the level of cost control on farm activities.

3.2 Direct Costing and Activity Based Costing in farm management

Economic analyses can be significantly improved by the availability of detailed and specific data provided by the new tools and systems adopted in PA. This abundance of data needs to be directed through structured processing that enables the transformation from a raw state in a structured and synthetic form, that conveys the information required in decision making. Crop choices, machinery renewal, use of external services are some examples of decisions that require the adoption of specific accounting tools to set cost comparisons and support decision making. Furthermore, in many cases general costs (e.g.: depreciation of machinery) are not correctly allocated to crops: they are allocated considering only the extension of the plots. Nevertheless this approach leads to significant evaluation errors in managerial choice, favoring complex products realized in small quantities, and disfavoring simple products realized in large quantities.
To address these issues, two main approaches have been proposed in accounting that support a structured decision making process: DC and ABC. DC is an accounting practice that is oriented at charging variable costs to products (Siegel & Shim, 2000: 141). ABC methodology has been developed to face the increasing level of fixed costs in the modern companies (Cooper & Kaplan, 1988; Johnson & Kaplan, 1987). Their allocation to products is complex and ABC has been developed as "*a methodology that measures costs and performances of activities, resources and cost objects, assigns resources to activities and activities to cost objects based on their use, and recognizes causal relationships of cost drivers to activities*" (Dierks & Cokins, 2000).
An ABC system is based on the idea that products make use of certain general activities developed inside the company and these activities require some resources to be done. It means that, first, the cost of the resources are allocated to the activities and, then, the costs of activities are allocated to the products (costs objects) using specifics activity drivers for every activity. In this way, it is possible to assign overhead costs to products in a more accurately and precise way. This logic enables managers to have a deeper control of how products or services, brands, customers, channels of distribution, or facilities consume resources and generate costs. Furthermore, this logic fosters the understanding of patterns of resource consumption at the micro level. Managers can have access to a deeper level of information that enables corrective actions directed to the enhancement of revenues, profitability and the reduction of costs. ABC prevents some distortions related to product cost information that arise from traditional accounting systems where the overhead (indirect costs) are arbitrarily attributed, usually in proportion to an activity's direct cost. Traditional systems create higher distortions when there are sophisticated production structures, with a wide range of products or services that require the assignment of large general costs.
The combination of DC and ABC enables to analyze cost supporting detailed managerial analysis based on a precise view of the cost of the single crop, considering its relative use of machinery and human resources. In agricultural and food literature there are only anecdotical examples and cases of application of DC and ABC to farm management. ABC has been applied in a number of case studies: fish processing in Finland (Setala & Gunasekaran, 1996), fish markets in Taiwan, combined with a linear programming technique (Lee & Kao, 2001), sawmilling in Finland (Korpunen, Mochan,

& Uusitalo, 2010), winemaking in Spain (González-Gómez & Morini, 2006), ornamental plant cultivation in Spain (González-Gómez & Morini, 2009). Only Chrenková (2011) proposes a complete analytical framework based on a on Microsoft Excel spreadsheet, not depended to a specific business.

Here, our purpose is to consider the specific information flows required by the use of a combination of DC and ABC in a FMIS. Modern ICT and PA technologies offer the possibility to collect a large amount of data that can be used to set a precise monitoring of costs with a reduced intervention by farmers, since automatic processes collect large part of the data and perform information processing activities.

The aim of this paper is to identify the information requirements for the development of a DC and ABC in a FMIS: we detail the model presenting data flows, then we propose a possible architecture of the system, and, finally, we show the reporting functionalities of this application.

4. ANALYSIS AND DESIGN METHODOLOGY

To define the requisites of the FMIS module dedicated to DC and ABC we started from the typical procedure suggested in literature: (1) interviews and definition of the activities; (2) measurement of the cost of the activities; (3) definition of the cost drivers; (4) definition of the activity rates; (5) allocation of costs to products and cost analysis (Anthony, Hawkins, & Merchant, 2010; Rafiq & Garg, 2002). We devoted particular attention at adopting a user-centric approach to foster future adoption by decision makers. In the next sections, we describe the phases of our study. According to the first point of the procedure, we conducted interviews to collect opinions from key users about the managerial decisions they take in their activity and how they can be supported by a structured economic analysis tool. Therefore, we traced DFD diagrams and modeled a system prototype according to point two, three and four. Finally, we defined reports and evaluated the results with key-informants referring to point five. In interviews, we focused on general questions and also on a specific case study. In the next subsections we detail these phases.

4.1 Collection of the requisites

Consistently with the user-centric approach, we investigated what specific outputs users are going to expect from the system and what data they can provide or can be automatically collected. This is coherent with the need to develop application that are focused on users’ needs and grants more chances of adoption (Sørensen et al., 2010b). We administered five interviews with experts and farming practitioners to define the context in which the system is expected to operate, the final cost objects, and a list of activities related to a specific crop: the local production of potatoes, a typical crop in the province of Bologna, Italy. We defined with informants a list of activities to give a parsimonious representation of what the main components of variable and fixed costs are. The output of this step is a list of activities, selected according with the 5% rule: if an activity accounts for less of the 5% of the time, it is not relevant and can be aggregated to other activities.

4.2 Design of the system

In designing the system, we combined the specifics proposed by users with the information requirements of a DC and an ABC system. We defined DFD diagrams to trace the data collection, transformation of data in information, and decision making, according to a structure similar to Fountas et al. (2006). A DFD diagram is composed by different elements (processes, external entities, data stores, and data flows) and is part of the Structured Systems Analysis and Design Methodology for designing information systems (Davis, 1998; Skidmore, 1997). We also modeled the database using Entity-Relationship diagrams according to Davis and Yen (1998) and created a working prototype in Microsoft Access, finally we defined specific reports according to key-informants requests. We validated the design in a meeting with key-users and also with a panel of four experts in agricultural technology.

4.3 Validation of the model and definition the reports

We developed a prototype of the system in a Microsoft environment and we evaluated it in the case study, devoting particular attention to the enhancement of reports, detailing the single analysis that our informants required. We set the parameters of what-if analysis and discussed the impact of the results proposed by the system on their decision making activity.

5. RESULTS

The results of this study include a rich framework related to the system design, with the support of our informants. In the next subsections, we present the DFD and E-R diagrams, the data sources for the application of DC and ABC approaches, and we describe the interfaces and the report section.

5.1 Conceptual model

We outlined the system after having collected the users' requirements during interviews. Interviewees stressed the need of a simple structure with clear procedures to insert data, process information, and analyze results on reports. Therefore, referring to Fountas et al. (2006), we developed a DFD diagram, shown in Figure 1, describing the structure of the system. The diagram includes three main areas: data collection, information processing and decision.
The data collection section is designed to support the transfer and recording from machines and equipment, human resources, service providers and warehouse. The effort is to register the majority of costs as direct costs on specific activities on a single crop. Therefore, for machines, human resources and service providers, costs are measured in terms of time spent in a specific activity. Material use is measured in terms of employed

quantity.
These data are collected in specific tables on the database: Figure 2 reports the synthetic design of the system showing an Entity-Relationship model.
Once the data are collected, in the Information part of the diagram in Figure 1, the system allocates direct costs to the crops. General costs need to be allocated according to an ABC procedure. Therefore, the system collects data about resource use. The Entity-Relationship diagram in Figure 2 shows the specific tables devoted to monitor resource use collecting data from the field. These raw data is combined with activity drivers defined in the setup of the system to generate activity rates and allocate general costs to single crops.

5.2 ABC development

For the allocation of general costs to crops and final products, after the identification of activities, for each activity a driver needs to be identified. The choice of the activity driver must be consistent with the consumption of the underlying resource. In other words, each time the activity is performed, it should generate the same consumption of the underlying resource and the same amount of costs (Anthony et al., 2010; Cooper & Kaplan, 1988).
For each activity, it is necessary to calculate the activity rate, which is the unitary cost of an activity. The activity rate is calculated dividing the overall cost of an activity by the overall volume of the activity. It is a common practice not to use at the denominator the overall volume of an activity, but the overall capacity of the resource. The denominator presents the maximum volume that would be possible to do with the resources assigned to the activity.
Table 1 shows the specific activity drivers we defined for the different types of resources. According to the request for simplification, we measured resource use mostly in terms of duration according also with the recent formulation of Time-Driven ABC (Kaplan & Anderson, 2007). We report also some viable alternatives that can be considered in the setup of the system.
The final step of the procedure is the allocation of cost to products. The allocation for each product unit is calculated multiplying the activity rate by the quantity of activity required by the unit of product. The overall cost of the product is the sum of the allocated costs plus the direct costs for each product-linked activity.

5.3 Interfaces and reports

Many of the data required to run the system can be acquired using automatic technologies or very structured approaches. Some examples are presented in the last column of Table 1. The system is designed to be hosted in a cloud-based system, that makes it accessible from different locations and also on the field. The design of interfaces to devices and tools goes beyond the objectives of this study, but the design of the system using SQL language in a Microsoft database allows a vast range of compatibility. In our prototype, we developed data input forms, and automated procedures that manage information and generate reports.

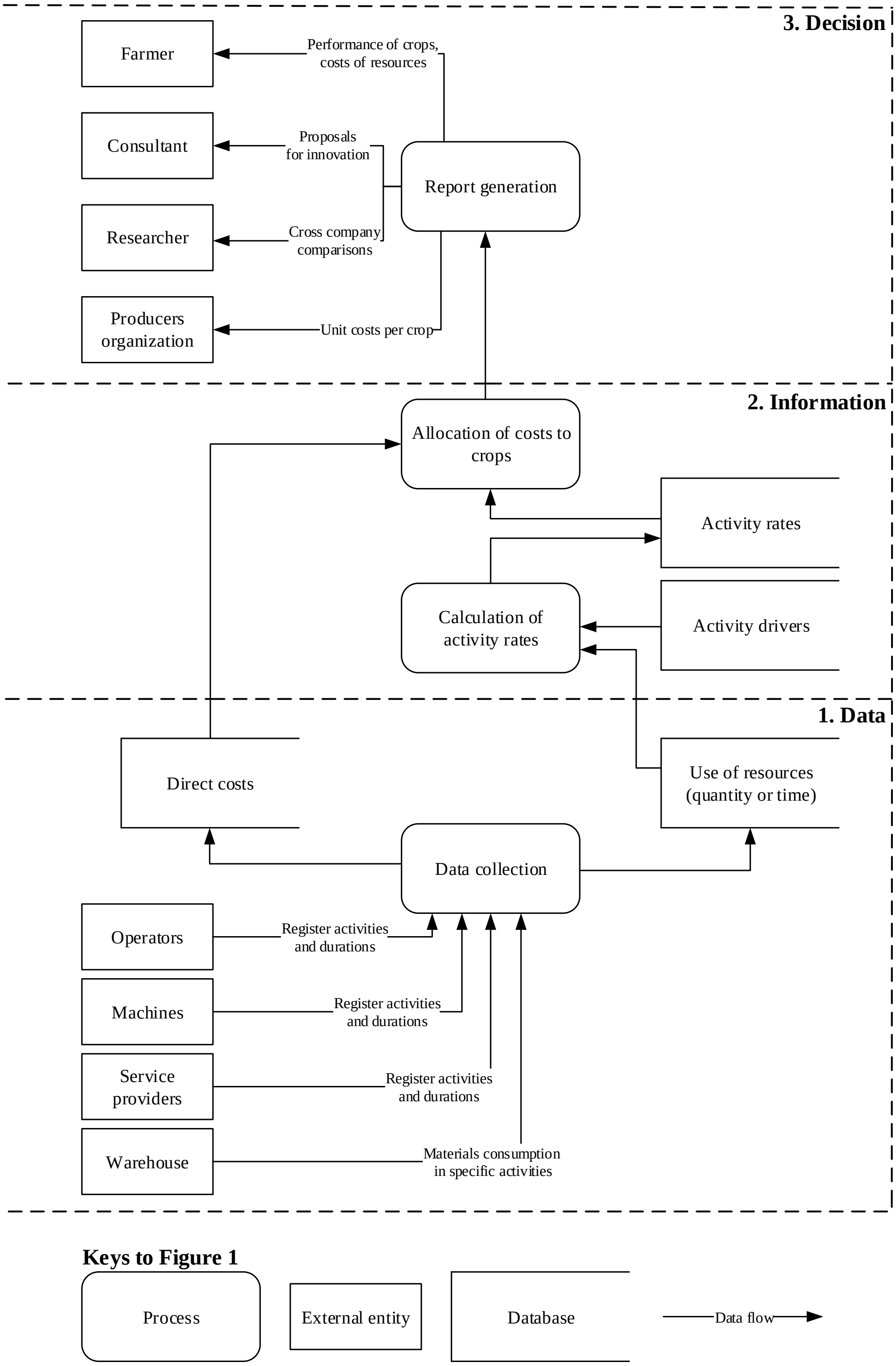

Figure 1. DFD of the system

C0110
Giacomo Carli, Maurizio Canavari. Toward a New Model of Farm Management Information Systems combining ICT, Activity Based Costing, and What-If Analysis. EFITA-WCCA-CIGR Conference "Sustainable Agriculture through ICT Innovation", Turin, Italy, 24-27 June 2013.

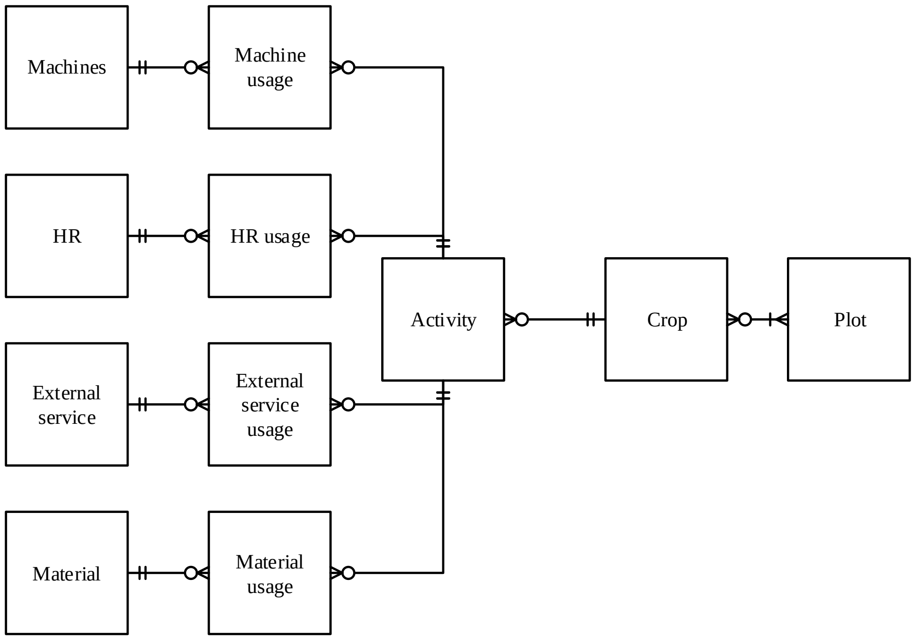

Figure 2. E-R diagram of the system adopting Crow's Foot notation (Davis & Yen, 1998)

Table 1. Data required by the ABC system

Type of resource	**Resource examples**	**Possible activity drivers**	**Measurement tool**
Machinery	Tractor	Time	Data from the machine
		Fuel consumption	ISO BUS (starting time, ending time, rpm per minutes)
			Level control
		Maintenance	Cost per maintenance
Human Resources	Farmer Employee Seasonal worker	Time	Manual
			Badge
		Quantity or number of final products	Number of final products
		Path (meters) per field (crop)	GPS per person associated with a plant of the crops per period
			GPS per person (measures time and the entry/exit from a field)
Material	Not reusable material	Quantity	Machine ISO BUS (to be developed)
Service	Any service	Time	GPS Manual
		Upfront cost	Single cost of the service

In the definition of reports we devoted particular attention to the requirements set during interviews. They asked for a cost control interface for the different crops of their farms: they were interested in understanding the impact of general costs on the different crops, allocating them not on the basis of the extension, but on the basis of the complexity of the production cycle. They also asked to perform simple simulations in terms of what-if analysis related to variation in selling prices, cultivated extensions, production per hectare. Combining these requirements, we designed a reporting system on Microsoft Excel linked to the database to reduce complexity and compatibility issues and leave the possibility of personal customization on reports. We combined a balance sheet designed to offer decomposed data per single crop, with a set of different what-if analyses.

6. DISCUSSION

The results of this study open the possibility to introduce in the growing literature about FMIS an application of the most recent systems for cost accounting (ABC and DC). We go in the direction of offering a significant support to the information processing phase in agricultural management. Moreover we build on the existing conceptual models (Sørensen et al., 2010a) offering development models that support the design of the economic module of a FMIS.

In our interviews, informants suggested to combine simplicity with a structured approach to provide farmers with a limited number of choices and the access to a platform that do not require sophisticated hardware and software investments.

A further contribution of this study is to offer a model that addresses cost management in FMIS. Many software houses are introducing cost analyses in their products, but in some cases they introduce custom approaches without referring to the solid guidelines of management theory. This framework can constitute a reference for developments compliant with the DC and ABC approaches.

7. CONCLUSIONS

As part of the literature about FMIS design and introduction, we focused on cost control, investigating the information needs related to the introduction of DC and ABC approaches in farm management with the support of a dedicated information system. We analyzed through interviews the requirements of farm managers and we combined them with the information needs of a cost analysis and management application. The conceptual model is detailed with a DFD and a E-R diagram. We developed a prototype of the system along with a set of reports that introduce a detailed view of costs per crop, allocating general costs. Finally we designed what-if analyses to enable a satisfactory decision making process.

We identify two areas of further investigation. First, the interface with tools and machines can be designed to support an automatic process of data collection. We consider that a staging area to consolidate data before introducing it in the database is a solution that protects from erroneous recordings and incomplete transmissions. Second, in the reporting section, we look towards the introduction of mathematical programming tools as a support for the definition of the optimal combination of crops per farm. Farms would benefit from the adoption of a sophisticated decision support system supported by operative research technologies that combines different decision variables.

8. ACKNOWLEDGEMENTS

This study is part of the on-going EU ICT-AGRI ERA-NET research project "RoboFarm", funded on the Italian side by the Italian Ministry of Agriculture, Food and Forestry Policies.

9. REFERENCES

Anthony, R. N., Hawkins, D. F., & Merchant, K. A. 2010. *Accounting Texts & Cases, 13E by Robert N. Anthony* (13th ed.). McGraw-Hill.

Chrenková, I. 2011. Controlling in the Conditions of Czech Republic. *AGRIS On-line Papers in Economics and Informatics*, 3(2): 3–14.

Cooper, R., & Kaplan, R. S. 1988. Measure costs right: make the right decisions. *Harvard Business Review*, 66(5): 96–103.

Davis, W. 1998. Data flow diagrams. In W. Davis & D. Yen (Eds.), *The Information System Consultant's Handbook*. CRC Press.

Davis, W., & Yen, D. 1998. Entity-relationship diagrams. In W. Davis & D. Yen (Eds.), *The Information System Consultant's Handbook*. CRC Press.

Dierks, P., & Cokins, G. 2000. *The CAM-I Glossary of Activity-based Management*. CAM-I.

Fountas, S., Wulfsohn, D., Blackmore, B. S., Jacobsen, H. L., & Pedersen, S. M. 2006. A model of decision-making and information flows for information-intensive agriculture. *Agricultural Systems*, 87(2): 192–210.

González-Gómez, J. I., & Morini, S. 2006. An Activity-Based Costing of Wine. *Journal of Wine Research*, 17(3): 195–203.

González-Gómez, J. I., & Morini, S. 2009. A model for cost calculation and management in a multiproduct agricultural framework. The case for ornamental plants. *Spanish Journal of Agricultural Research*, 7(1): 12–23.

Johnson, H. T., & Kaplan, R. S. 1987. *Relevance Lost: The Rise and Fall of Management Accounting*. Harvard Business Press.

Kaplan, R. S., & Anderson, S. R. 2007. *Time-Driven Activity-Based Costing: A Simpler and More Powerful Path to Higher Profits*. Harvard Business Press.

Kay, R., Edwards, W., & Duffy, P. 2011. *Farm Management*. McGraw-Hill Education.

Korpunen, H., Mochan, S., & Uusitalo, J. 2010. An Activity-Based Costing Method for Sawmilling. *Forest Products Journal*, 60(5): 420–431.

Lee, T.-R., & Kao, J.-S. 2001. Application of simulation technique to activity-based costing of agricultural systems: a case study. *Agricultural Systems*, 67(2): 71–82.

Nash, E., Dreger, F., Schwarz, J., Bill, R., & Werner, A. 2009. Development of a model of data-flows for precision agriculture based on a collaborative research project. *Computers and Electronics in Agriculture*, 66(1): 25–37.

Nikkilä, R., Seilonen, I., & Koskinen, K. 2010. Software architecture for farm management information systems in precision agriculture. *Computers and Electronics in Agriculture*, 70(2): 328–336.

Rafiq, A., & Garg, A. 2002. Activity based costing and financial institutions: Old wine in new bottles or corporate panacea? *The Journal of Bank Cost & Management Accounting*, 15(2): 12–29.

Setala, J., & Gunasekaran, A. 1996. Activity-based costing and management--a way to improve the profitability of fish processing? *Production and Inventory Management Journal*, 37(4): 63–69.

Siegel, J. G., & Shim, J. K. 2000. *Accounting Handbook*. Barron's Educational Series.

Skidmore, S. 1997. *Introducing Systems Analysis*. Macmillan Publishers Limited.

Sørensen, C. G., Fountas, S., Nash, E., Pesonen, L., Bochtis, D., Pedersen, S. M., et al. 2010a. Conceptual model of a future farm management information system. *Computers and Electronics in Agriculture*, 72(1): 37–47.

Sørensen, C. G., Pesonen, L., Bochtis, D. D., Vougioukas, S. G., & Suomi, P. 2011. Functional requirements for a future farm management information system. *Computers and Electronics in Agriculture*, 76(2): 266–276.

Sørensen, C. G., Pesonen, L., Fountas, S., Suomi, P., Bochtis, D., Bildsøe, P., et al. 2010b. A user-centric approach for information modelling in arable farming. *Computers and Electronics in Agriculture*, 73(1): 44–55.

Voulodimos, A. S., Patrikakis, C. Z., Sideridis, A. B., Ntafis, V. A., & Xylouri, E. M. 2010. A complete farm management system based on animal identification using RFID technology. *Computers and Electronics in Agriculture*, 70(2): 380–388.