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Review

Obstacles and features of Farm Management Information Systems: A systematic literature review

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ABSTRACT

Various Farm Management Information Systems (FMISs) have been developed to support the management of the farm businesses. These FMISs typically support the different domains of the agricultural sector, such as arable and dairy farming; and include different set of features, such as crop, field, and financial management. These FMISs also have to deal with diverse obstacles during their development and adoption, such as lack of standardized data, cost and usability. Though several papers have been published in the past several years on this topic, there has been no explicit attempt to systematically review these papers to identify and characterize the features and obstacles. The objective of this study is to identify and describe the state-of-the-art of FMISs and as such pave the way for further research and development of FMISs. We applied a systematic literature review protocol in which we included the literature published from 2008 to 2018. We found 1048 papers of which 38 papers were selected as primary studies that we analyzed further in detail. From the detailed analysis, we identified 81 unique FMIS features and 51 unique obstacles of FMISs. We have systematically ranked the identified features and obstacles and describe the key associated aspects. These aspects include the agricultural domains, modeling approaches, delivery models, and identified stakeholders.

1. Introduction

A Farm Management Information System (FMIS) or, in short, a Farm Management System (FMS) is developed to support the management of diverse farm enterprises. An FMIS is essentially a Management Information System (MIS) for the agriculture sector. According to Waston et al. (1991) an MIS is defined as: “an organizational method of providing past, present and projected information related to internal operations and external intelligence.” An MIS supports decision making by providing timely information about the planning, control and operational functions of an organization (Waston et al., 1991). By the same token, an FMIS supports timely decision making within farm enterprises. Over the years MISs for agriculture have developed from simple farm data recording systems into extensive FMISs (Fountas et al., 2015a). Sørensen et al. (2010) defines an FMIS as: “a planned system for the collecting, processing, storing and disseminating of data in the form of information needed to carry out the operations functions of the farm.” FMISs can support decision making by finding the best practices for farm management (Fountas et al., 2015a). The main purpose of current FMISs is to reduce the production costs, maintain high product quality and safety, and to comply with agricultural standards (Fountas et al., 2015a). In general, an FMIS supports decision making and helps with keeping track of the current business processes to maximize the profit of a farm.

To understand FMISs, it is important to know which features they support, which obstacles are encountered in developing and using FMISs, and the context in which the FMISs are used. In this paper, we define features of an FMIS as user-visible characteristics. All features together constitute to what we refer as an FMIS. Widely supported features of FMISs include Feed management, Financial management, and Labour management (Allen and Wolfert, 2011). Developers of FMISs face many obstacles in providing the desired FMIS features. Likewise, a substandard FMIS creates a number of obstacles for end users. In this study, we regard an obstacle in general terms as any problem related to the development or the use of FMISs. Since the adoption of FMISs is directly related not only to the features provided but also to the obstacles faced, an SLR of FMISs also needs to consider studies that identify and describe the current obstacles and open issues of FMISs.

It turns out that different FMISs are offered to different domains of the agricultural sector. For instance, while some FMISs focus on arable farming, others concentrate on livestock farming. Different FMISs have different licensing and delivery models. They can for example run on mobile phones or desktop computers and can be commercial or non-

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commercial. FMISs can be described using formal software architecture models. These models address specific concerns of the stakeholders of the system (ISO/IEC/IEEE, 2011). In order to describe FMISs, it is also important to identify the stakeholders and which features are of value to them.

In the past years, FMISs have been considered in multiple studies. There is, however, no structured information about what constitutes as an FMIS and which features it can support. FMISs have been considered from different perspectives, but no clear and consistent set of features of FMISs has been defined so far. Identifying and describing the features and obstacles is essential for both the practitioners who aim to build FMISs and researchers who study FMISs. In this paper, we provide a systematic literature review (SLR) to address these issues. The goal of this SLR is to identify all FMISs described in the scientific literature and their common obstacles and features. For carrying out the SLR, we have adopted the protocol as defined by Kitchenham et al. (2009). In this research, the SLR is performed to identify all prior research about FMISs and to give a reliable and extensive review of all preliminary research.

The remainder of the paper is organized as follows. Section 2 shows the related work. Section 3 describes our review protocol in detail. Section 4 presents the results of the SLR. Section 5 presents the discussion and finally Section 6 concludes the paper.

2. Related work

In this section, we describe the limited review literature on FMIS that we were able to find. To our best effort we were unable to find a systematic literature review on FMISs, and in this respect, the present study represents a pioneering effort that paves the way for systematically reviewing the state-of-the-art knowledge on FMISs. Particularly, we were able to find three closely related scientific papers and one professional publication which we describe below, together with other relevant literature.

Fountas et al. (2015a) evaluates current FMIS designs and solutions and describes the current situation and future perspectives. They present the state-of-the-art of FMIS applications in 2015, in order to provide a basis for future FMISs. They found a total of 141 different commercial FMISs, coming from 75 software vendors. From the commercial solutions, they extracted eleven different major features for FMISs: Field operations management, Best practice, Finance, Inventory, Traceability, Reporting, Site-specific, Sales, Machinery management, Human resource management, and Quality assurance.

The second and third related scientific papers are the studies conducted by Robbemond and Kruize (2011), Allen and Wolfert (2011). Robbemond and Kruize (2011) present the functionalities from multiple FMISs. The primary goal of this research was to gain insight into the data standards used in FMISs. This study identified 264 farm management applications coming from 143 different software vendors. This study identified the following eleven major features: Procurement, Inventory management, Product Management, Marketing and sales, Human resource management, Technology management, Energy management, Real estate management, Quality assurance, Finance, and Accounting. A similar review was done by Allen and Wolfert (2011) covering only the livestock domain. They describe the current farm ICT tools in this domain, but in fact these tools are FMISs with sometimes restricted functionalities. The study states that interconnectivity of tools and Internet speeds are bottlenecks for the adoption of FMIS. This report identified 127 tools, available for New Zealand farmers, and divided them into the following seven categories: Feed management, Financial management, Labour management, Nutrient management, Resource management, Stock management, and Strategic planning.

The third relevant review publication is a website that presents 156 farm management software packages. Capterra (2018) filters the different packages based on the following thirteen functionalities: Barcoding/ RFID, Contract management, Crop management, Customer management, Financial management, Greenhouse management, Inventory management, Labor management, Livestock management, Order processing, Pricing management, Supplier management, and Traceability.

Besides the above studies, there is a secondary study on the information management of farms by Lawson et al. (2011). This study presents the results of a survey on the perception of farmers on advanced information systems and advanced farming systems in four European countries. In a survey, they asked farmers: "Is the use of possible computer documentation helpful for dealing with government agencies, landlords, consumers etcetera?". A little over 20% of the farmers answered affirmatively, but the majority of the farmers was unsure. They, however, state that large farms are among the early adopters of precision farming practices.

The related work identified multiple functionalities of FMISs, but none is based on a systematic literature review. The primary motivation for this SLR is, therefore, the lack of a systematic review of FMISs.

3. Review protocol

The guidelines for the SLR used in this report are the guidelines from Kitchenham et al. (2009). The guidelines of Kitchenham et al. are adopted from SLR guidelines used in medical literature and adapted for software engineering. For our SLR we defined a protocol shown in Fig. 1 adapting the protocol used by Gurbuz and Tekinerdogan (2018), Koksal and Tekinerdogan (2017) which are also based on Kitchenham et al. (2009). Kitchenham et al. (2009) defines an SLR as "a means of identifying, evaluating and interpreting all available research relevant to a particular research question, or topic area, or phenomenon of interest." The first step was the identification of research questions, which lead to the search strategy and resulting search strings in the second step. The definition of the search strategy included the selection of search strings and the sources where to search. The definition of the search strategy was an iterative process, where the output of one search string was used to adjust the subsequent search string. In step three we defined the criteria on which we selected the studies. In the fourth step, we applied the criteria to the search results. After this step, we got the articles that we used for a thorough assessment. This assessment was done based on a quality assessment method. In the fifth step, we started with a data

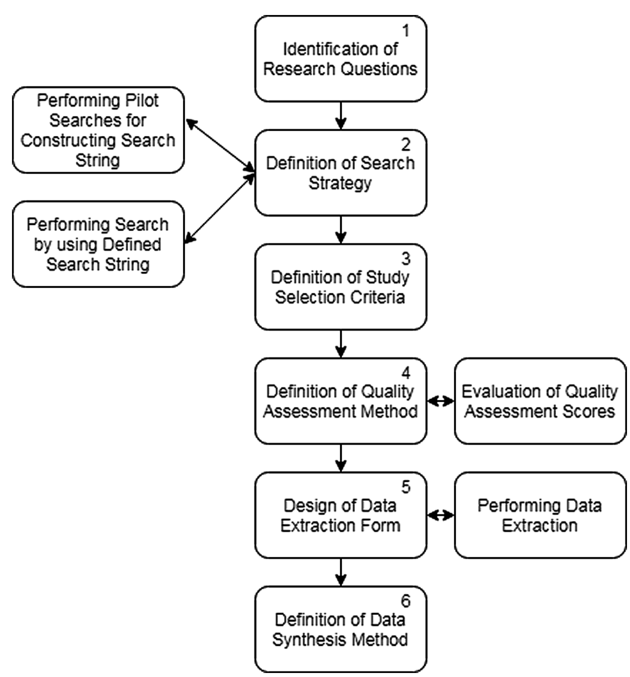

Fig. 1. Review protocol for our SLR. Adapted from Gurbuz and Tekinerdogan (2018) and Koksal and Tekinerdogan (2017).

extraction form that allowed useful data extraction from the selected papers. The third, fourth and fifth step were iterative. Finally, in the sixth step, we defined methods for data synthesis and presentation of the data.

3.1. Research questions

From the objective of this research we derived the following three research question to which the SLR should provide answers:

- RQ1: What are the current FMISs described in the literature?
  - RQ1.1: Which domains are supported?
  - RQ1.2: Which modeling approaches are applied?
  - RQ1.3: What are the delivery models?
  - RQ1.4: Who are the identified stakeholders?
- RQ2: What are the features of existing FMISs?
- RQ3: What are the obstacles to existing FMISs?

These research questions are answered using primary studies that were selected by our thorough quality assessment method. The first research question is answered by identifying FMISs described in the studies. For the first sub-question of question one, we looked at which domains of the agricultural sector FMISs were applied (e.g. Livestock, Arable farming). For the second sub-question we checked if the modeling approach is described and if there are diagrams that represent the software architecture. The diagrams can follow informal (boxes-and-lines) or formal (UML or comparable notation) modeling methods (Van Vliet, 1993). For the third sub-question we describe the delivery model as a combination of the software type, the FMIS type, and the software license. First, the software type is described based on the distinction between applications and platforms. Second, the FMIS type is a web-, mobile-, or desktop FMIS. Third, the software license is described, it can be developed by academic researchers (academic) or by a company (commercial). The stakeholders, that we identified in the fourth sub-question, are defined as the persons or groups of persons mentioned in the primary studies. The second research question is addressed by listing the features sorted by the frequency with which they were mentioned. For the third research question, we identified the obstacles mentioned in the primary studies.

3.2. Search strategy

To be able to answer the research questions presented in the previous sub-section we performed a systematic search through the available literature in the following digital libraries that publish high-quality papers: IEEE Xplore, ACM Digital Library, Wiley Interscience, Science Direct, Springer, and ISI Web of Knowledge. This selection is based on the sources used in other SLRs, such as (Gurbuz and Tekinerdogan, 2018 and Koksal and Tekinerdogan, 2017). Agricultural software is a fast developing research topic and therefore results from more than a decade ago will probably not be relevant anymore. Therefore, literature from the past eleven years (from 2008 to 2018) was used in this study. The targeted sources of papers were; journal papers, conference papers, workshop papers, and white papers. To find as many relevant results as possible, both an automated and a manual search were performed. The automated search was performed with the help of search strings in the previously stated sources. A manual search was performed by manually browsing the reference list of the papers that were discovered by the automated search (snowballing). For each source, the search string had a different syntax but in general, came down to the following query:

"(Farm OR Agri) AND (Manage* OR Information) AND (Software OR System* OR Tool OR Platform)"*

The results of the search query are listed in column *a* of Table 3. The source with the most studies was ISI Web of Knowledge with 422 studies, and the source with the smallest number of studies was ACM digital library with 108 studies. In total 1028 papers were identified via the automated search and 20 papers were added via manual search.

Table 1
Study selection criteria.

No.	Criterion
EC1	Papers without full text available
EC2	Papers not written in English
EC3	Duplicate publication from multiple sources
EC4	Papers do not relate to the agricultural sector
EC5	Papers do not relate to management information systems
EC6	Papers do not validate the proposed study
EC7	Papers which are experience and survey papers

3.3. Study selection criteria

The search string had a broad scope intentionally because we did not want to miss any potentially interesting research. This broad scope has led to a large number of papers, from which we filtered the most relevant ones using the selection criteria presented in Table 1. The selection criteria were applied manually first by reading the title and abstract of the study; which brought down the number of papers to 78 (column *b*, Table 3), including the papers found by the manual search. Secondly, we retrieved and read the complete article and applied the selection criteria, which brought down the number of papers to 43.

3.4. Study quality assessment

The 43 included studies were subsequently assessed for quality. Quality assessment was done by reading them entirely and applying the quality criteria presented in Table 2. These criteria are an adaptation of the criteria presented in Kitchenham et al. (2009) and from similar SLRs. We chose the criteria based on their influence on the quality of the final product. Points were given to each of the eight criteria based on the following scale: yes = 1, somewhat = 0.5, no = 0. For example, a full point was given for Q1 if the aim of the study was stated clearly in the introduction (expected place), and no point (0) was given if the aim of the study was not stated in the article. A half point (0.5) was given if the aim was vaguely stated, or not at the expected place.

We decided to exclude studies with a score lower than four points out of eight, to maintain a high-quality input of primary studies for this secondary study. We, therefore, excluded five studies with a score of less than four points and therefore had a total number of 38 studies, to which we refer as the primary studies (column *c*, Table 3). The quality assessment scores for the included 43 studies can be found in Fig. 2.

3.5. Data extraction

We read the 38 primary studies and extracted the required data for our analysis with the help of our data extraction form. To make the data

Table 2
Quality assessment criteria.

No.	Question
Q1	Are the aims of the study clearly stated?
Q2	Are the scope and context and experimental design of the study clearly defined?
Q3	Are the variables in the study likely to be valid and reliable?
Q4	Is the research process documented adequately?
Q5	Are all the study questions answered?
Q6	Are the negative findings presented?
Q7	Are the main findings stated clearly? regarding creditability, validity, and reliability?
Q8	Do the conclusions relate to the aim of purpose of the study? Reliable?

Table 3
Overview of search results and study selection.

Source	*After automated and manual search*	*After applying selection criteria*	*After reading complete study and quality assessment*
IEEE Xplore	111	20	7
ACM Digital Library	102	10	5
Wiley Interscience	120	1	0
Science Direct	138	7	6
Springer	135	6	1
ISI Web of Knowledge	422	14	7
Manual search	20	20	12
Total	1048	78	38

extraction form we first read three randomly selected articles and defined the data extraction form based on these papers. Afterwards, we used the data extraction form on five other, randomly selected, studies and extracted the data. After multiple iterations, we came to the data extraction form available in Appendix A. This form contains 28 elements, which includes basic information such as title, publication year and authors and specific information about software characteristics, such as the software license. It also contains elements needed for answering the research questions like the name of the FMIS, the architectural model used, the obstacles identified and the features identified of FMISs. At the end of this form, there is room for notes and the quality assessment. The resulting data from this form is further analyzed in MS Excel to find possible trends. We identified 71 stakeholders, 122 obstacles, and 401 features with the help of the form.

3.6. Data synthesis

The data synthesis is the synthesis of the information that we can derive from the data obtained by the data extraction from step five (see Fig. 1. All studies name their domains, obstacles, stakeholders, and features with slightly different names. We started by synthesizing synonyms. To be able to discover a trend in the data we identified umbrella concepts that can group all these variations. For the domain, we went from ten different domains to eight domains. For the stakeholders, we went from 71 different stakeholder names to 22 different names. We went down from 122 different names for the obstacles to 53 different names. From the total of 401 identified features, we came to a total of 81 features after synthesis.

4. Results

In this section, we first discuss relevant statistics about the 38 primary studies. In the second part of the section, we present the results corresponding to the three research questions.

4.1. Main statistics

The 38 primary studies that were included in this research are listed in Table 4. The publication year of these studies ranges from the years 2008 till 2017. The year-wise distribution can be seen in Fig. 3. By far the most popular publication channel is “Computers and Electronics in Agriculture” with 12 primary studies. The second most popular publication channel is “Precision agriculture (’13 & ’15) with two primary studies. ISI Web of Knowledge and IEEE Xplore were the most popular sources for the primary studies, with seven studies directly found via these digital libraries.

4.2. RQ1: What are the current FMISs described in the literature?

In the primary studies the following FMISs were mentioned: Ifarma, FARMnet, Kilo, Fieldtouch, WIDHOC, FARMA, Ifarm, Afimilk and Mark online. Only one FMIS was described twice: Ifarma, the rest were only

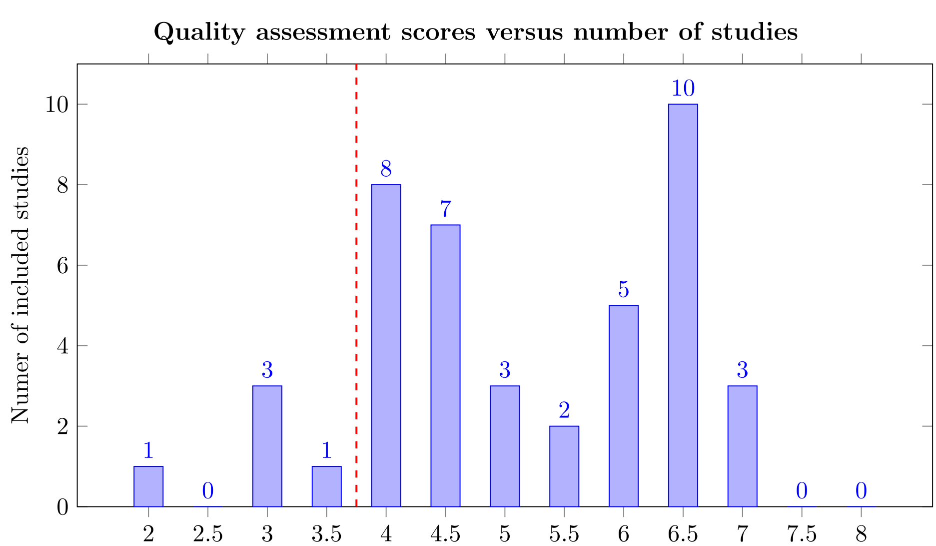

Fig. 2. The quality score distribution for the 43 studies after applying the study selection criteria. The studies on the left of the red dashed line are excluded from the results due to their low quality. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 4
The 38 primary studies used as input for the SLR.

Zheleva et al. (2017)	2017	Murakami et al. (2013)	2013	Paraforos et al. (2016)	2016
Hewage et al. (2017)	2017	Burlacu et al. (2013)	2013	Sørensen et al. (2010)	2010
Kjær (2008)	2008	Jiang and Zhang (2013)	2013	Novkovic et al. (2015)	2015
Khaydarov et al. (2012)	2012	Yan-e (2012)	2012	Robbemond and Kruize (2011)	2011
Honda et al. (2014)	2014	Yu and Yongjun (2010)	2010	Bligaard and Online (2014)	2014
López-Riquelme et al. (2017)	2017	Paraforos et al. (2017)	2017	Cojocaru et al. (2014)	2014
Kruize et al. (2016)	2016	Fountas et al. (2015a)	2015	Ampatzidis et al. (2016)	2016
Barmpounakis et al. (2015)	2015	Kaloxylos et al. (2014)	2014	Fountas et al. (2015b)	2015
Carli and Canavari (2013)	2013	Berger and Hovav (2013)	2013	Magne et al. (2010)	2010
Voulodimos et al. (2010)	2010	Kaloxylos et al. (2012)	2012	Allen and Wolfert (2011)	2011
Li et al. (2010)	2010	Sørensen et al. (2011)	2011	Tsiropoulos and Fountas (2015)	2015
Chen et al. (2016)	2016	Nikkilä et al. (2010)	2010	Tsiropoulos et al. (2013)	2013
Bojan et al. (2015)	2015	Tsiropoulos et al. (2017)	2017		

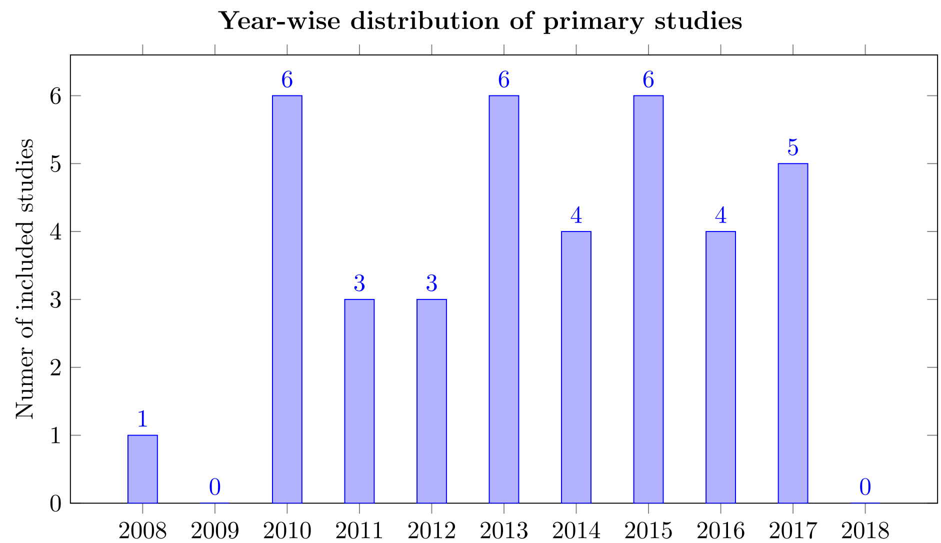

Fig. 3. The year-wise distribution for the 38 primary studies.

described once. Ifarma is a Greek commercial integrated farm management application (Paraforos et al., 2016). Most studies did not name a specific FMIS or had no name for their proposed design. Therefore, the answers to the sub-questions are based on all 38 primary studies, i.e. the ten studies that discussed a named FMIS and the other 28 studies that presented unnamed FMISs.

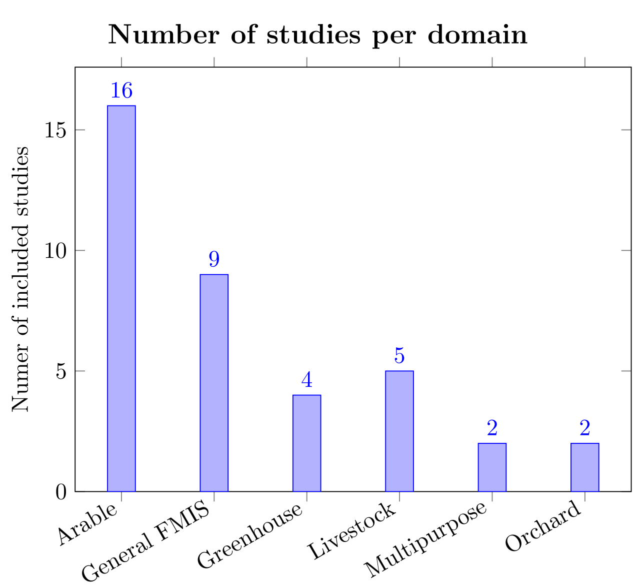

Fig. 4. Number of included studies coming from a specific domain. The category "General FMIS" includes the studies that could not be traced back to one domain.

4.2.1. RQ1.1: Which domains are supported?

In Fig. 4 the primary studies are divided into five domains that were identified. From this table, it can be seen that the domain that is described the most is Arable farming, with sixteen primary studies. This can be attributed to the fact that the Arable farming domain is ahead regarding the use of precision agriculture practices and the adoption of MIS. The second most described domain with five studies is Livestock. Domains that are mentioned less in the studies are Greenhouse (4), Multipurpose farm (2), and Orchard (2). Nine studies did not specify a specific domain and described one or multiple FMIS(s) that could not be traced back to one domain. Interestingly we did not identify any FMIS for the Forestry or Fishing and Aquaculture domain (Food and Agriculture Organization of the United Nations, 2011).

4.2.2. RQ1.2: Which modeling approaches are applied?

Software modeling is needed to support the communication between different stakeholders involved in the development of software. There are multiple software modeling notations; the modeling notation can be straightforward with just simple boxes-and-lines, or by following the more complicated Unified Modeling Language (UML) (Van Vliet, 1993). UML is the de facto industry standard used for making object-oriented analyses and designs for information systems (Fowler et al., 2004). Other methods for modeling are entity-relationship (E-R) and data flow diagrams. The E-R diagram is a basis for representing a unified view of the data model (Chen, 1976) and shows the data layer of a system, the Data flow diagram is a visual tool to depict logic models and

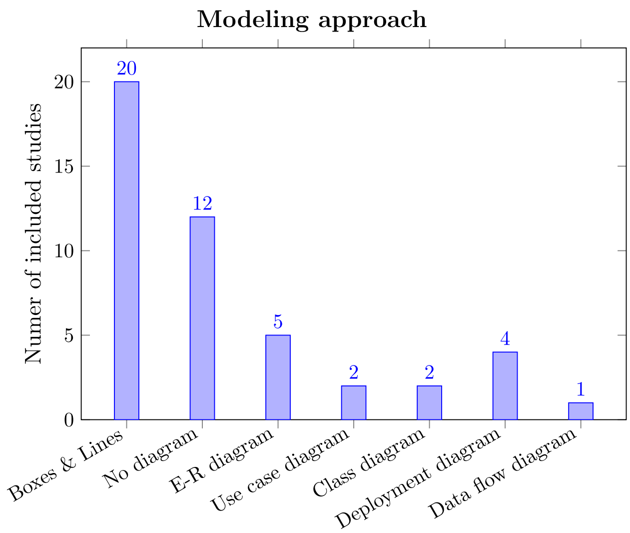

Fig. 5. The used modeling approach for the 38 primary studies. A study can describe zero (No Diagram), one, or multiple modeling approaches.

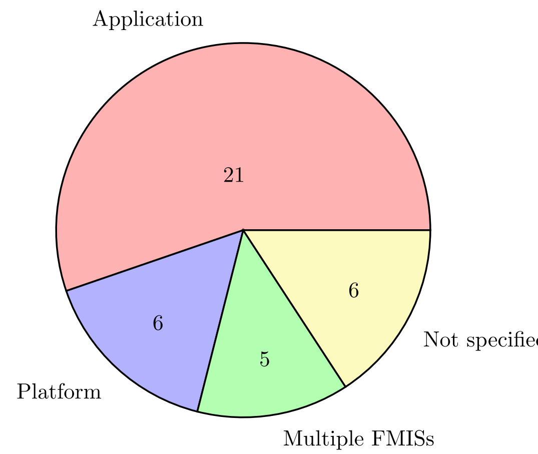

Fig. 6. The number of papers describing the software type.

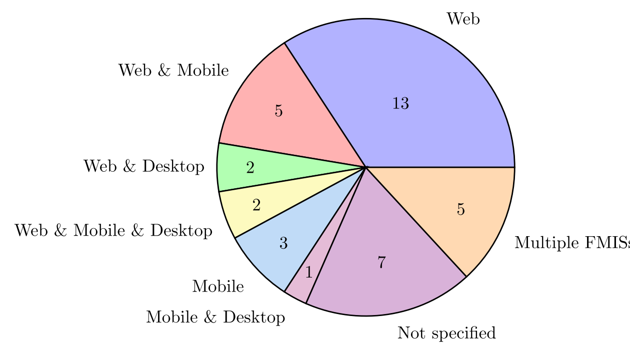

Fig. 7. The number of papers describing the FMIS type.

expresses data transformation in a system (Li and Chen, 2009).

Multiple primary studies describe the software architecture of the FMIS software with models. Fig. 5 shows that the boxes-and-lines description occurs 20 times while 12 studies do not have any architectural model at all. The E-R diagram is presented five times in the primary studies, The use case diagram (2 times), class diagram (2 times), and deployment diagram (4 times) are the UML diagrams that appear in the primary studies. Where the use case diagram visualizes use cases and their actors, the class diagram describes the types of objects in the system and the various kinds of static relationships that exist among them, and the deployment diagram shows the physical relationships among software and hardware components in the delivered system (Fowler et al., 2004). The Data flow diagram is only identified once.

Multiple studies use more than one modeling approach. Table 5 shows the modeling approaches used by each primary study. for instance, a Deployment diagram and Use case diagram are used within one study, and a Data flow diagram and an E-R diagram are shown within one study. However, no study uses more than two models, and the 14 more complex models are coming from 10 studies.

4.2.3. RQ1.3: What are the delivery models?

An FMIS can be delivered as an application or as a platform. In this study, we define a platform as software with a plug-in architecture that allows users or other companies to write custom controllers or extend its functionality easily (Diankov and Kuffner, 2008). An application is defined as a computer program that can directly perform an activity (Ceruzzi, 2003) and can be deployed locally and used directly. From Fig. 6 we see that the described software type was in most studies (21 out of 38) of the application type and in six studies of the platform type. There were six studies of which we were not able to retrieve the delivery model because it was not explicitly stated or shown in the models. Furthermore, we identified five studies which described multiple FMISs in their work and we could, therefore, not categorize these studies in the application, or platform category.

The application and platform structure can again be divided into three FMIS types: The Web FMIS, the Mobile FMIS, and the Desktop FMIS. Where the Desktop FMIS is installed and executed on a desktop or laptop, the mobile FMIS can run entirely on the mobile device, or it can be a web FMIS specialized for a mobile phone (Wasserman, 2010). A Web FMIS can be accessed via a browser and can often be accessed via

Table 5
The primary studies sorted per modeling approach. A study can describe zero (No Diagram), one, or multiple modeling approaches. The bold font indicates studies that present multiple model descriptions.

Model Description	Studies
Boxes & Lines	Zheleva et al. (2017), Kjær (2008), Khaydarov et al. (2012), Honda et al. (2014), López-Riquelme et al. (2017), Voulodimos et al. (2010), Chen et al. (2016), Bojan et al. (2015), Burlacu et al. (2013), Yan-e (2012), Yu and Yongjun (2010), Paraforos et al. (2017), Kaloxylos et al. (2012), Nikkilä et al. (2010), Paraforos et al. (2016), Bligaard and Online (2014), Cojocaru et al. (2014), Ampatzidis et al. (2016), Magne et al. (2010), Tsiropoulos and Fountas (2015)
No Diagram	Hewage et al. (2017), Murakami et al. (2013), Jiang and Zhang (2013), Fountas et al. (2015a), Berger and Hovav (2013), Sørensen et al. (2011), Tsiropoulos et al. (2017), Novkovic et al. (2015), Robbemond and Kruize (2011), Fountas et al. (2015b), Allen and Wolfert (2011), Tsiropoulos et al. (2013)
E-R Diagram	Carli and Canavari (2013), Voulodimos et al. (2010), Paraforos et al. (2017), Paraforos et al. (2016), Tsiropoulos and Fountas (2015)
Use Case Diagram	Barmpounakis et al. (2015), Li et al. (2010)
Class Diagram	Kruize et al. (2016), Li et al. (2010)
Deployment Diagram	Kruize et al. (2016), Barmpounakis et al. (2015), Kaloxylos et al. (2014), Sørensen et al. (2010)
Data Flow Diagram	Carli and Canavari (2013)

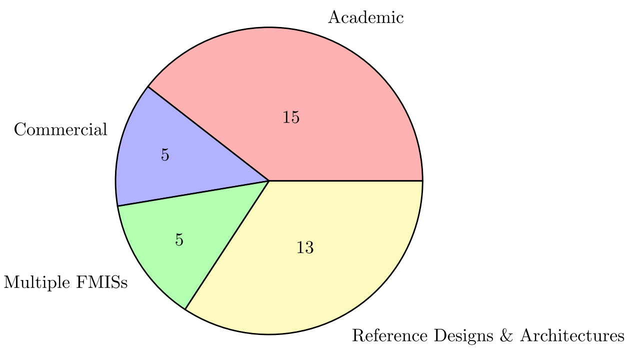

Fig. 8. The number of papers describing the software license.

both computers and mobile devices. From our data synthesis method, we also got results for the FMIS types used. The results are presented in Fig. 7. From the results, we see that the Web FMIS is described the most, in 21 studies. The Mobile application is described in eleven studies and the Desktop application in five studies. From the figure, we furthermore see that studies describe combinations of the FMIS types and that no standalone Desktop application is described. From six studies we were not able to retrieve the FMIS type since they were not stated explicitly or shown in models. Again five studies present an overview of multiple FMISs and, therefore, we were not able to retrieve the FMIS type of these studies.

The software license of FMISs can be of two types: Academic or Commercial. The Academic license is described as the license for software that is currently under research or has been developed by academic researchers. Commercial software is defined as software developed by a commercial company. In Fig. 8 the software licenses from the primary studies are presented. From this Figure, it is seen that fifteen studies described the license as academic. Five studies described a commercial software solution. We also see that 13 studies show a reference design or a reference architecture. These 13 studies present a design only and can therefore not be gathered under the Academic license. We furthermore have five studies that describe multiple FMISs, and we were therefore not able to put the licenses within one parameter.

4.2.4. RQ1.4: Who are the identified stakeholders?

The Project Management Institute (PMI) defines a stakeholder for a project as follows: "an individual, group, or organization, who may affect, be affected by, or perceive itself to be affected by a decision, activity, or outcome of a project" (Project Management Institute, 2013). In total, we identified 22 different stakeholders. They are presented in Table 6 sorted by their frequency in the primary studies.

We also looked at the number of stakeholders types per primary study. The eleven stakeholders that appeared four times or more in the primary studies are shown in Table 7. All primary studies show that the farmer is the primary stakeholders, as expected. The data also shows that the government is the second most mentioned stakeholder. A number of other stakeholders are mentioned for FMISs, for example, Veterinarian, Contractor, and Agricultural advisor.

4.2.5. Characterization of FMISs

In the previous sub-sections, we have shown the various characteristics of FMISs, which are the domains, the modeling approaches, the software type, the FMIS type, and the software license. In this subsection, we look at FMIS mentioned by name. We describe these FMISs based on the characteristics that are identified so far. This information is presented in Table 8; the Study ID refers to the studies listed in Table 4. From this table we see that most FMISs have the Application structure, are modeled with boxes and lines, are under an Academic license, and are available as a web application. The most occurring domain is arable farming.

4.3. RQ2: What are the features of existing FMISs?

In total we identified 81 different features of FMISs in the 38 primary studies. A table with all 81 features in descending order is presented in Appendix B and the features that occurred seven times or more are further described below based on their explanation given in the primary studies.

Table 6
The identified stakeholders and their relationship to FMISs.

Stakeholder name	Description	#
Farmer	Responsible person on the farm and end-user of the system.	38
Governmental	Umbrella term for multiple stakeholders that relate to the government. Has an interest in FMIS for registration purposes, and to obtain farm information	10
Agricultural expert	Has expert knowledge about the agricultural sector and can be used for requirements for FMISs.	7
Farm employee	Works on the farm and has to work with the FMIS.	6
Research Institute	Multiple kinds of researchers and institutes can be used as knowledge input for FMISs.	6
FMIS developer	Develops the FMIS and its underlying software.	5
Input supplier	Delivers inputs to the farm, these inputs can be registered in an FMIS	5
Agricultural advisor	Helps the farmer with making decisions based on their knowledge, an FMIS can assist them.	4
Agriculture service provider	Assists the farmer with the providence of services. Can use FMIS for registration purposes.	4
Contractor	Hired by the farmer to perform field tasks. FMISs can improve the communication with the farmer.	4
Equipment producer	Makes new machinery for the farmer, an FMIS can provide machinery management.	4
Customer	Companies and other entities greater than an individual consumer. FMIS can provide details about the purchased products.	3
Administrator	Can setup system, and manages the FMIS. Is not necessary the FMIS developer.	2
Farmers association	Organized group of farmers with common interests. Want FMIS for implementation of modern technology.	2
Neighbour	Is influenced by decisions of FMIS (Odor nuisance, noise disturbance, etcetera).	2
Non-governmental	Group of persons with their own (ecological) interest that can be intertwined with the FMIS.	2
Product processor	FMIS can provide information on products coming from the farm.	2
Veterinarian	Can use the FMIS for retrieving animal information and can register veterinarian actions.	2
Accountant	Can use the financial modules of FMISs to verify and assist the farmer with bookkeeping.	1
Equipment dealer	Can provide machinery support and services via the FMIS.	1
Media	Provides communication with the outside world and has an influence on the farm image.	1
Weather service provider	Provides weather information as input for the FMIS.	1

Table 7
The stakeholders that are mentioned four times or more in the primary studies. The name of the stakeholder in the table is not necessarily the name of the stakeholder in the primary study due to the data synthesis step mentioned in Section 3.6.

	Stakeholder categories										
Study	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**	**S11**
Kjær 2008	X			X							
Voulodimos et al. 2010	X										
Li et al. 2010	X										
Yu & Yongjun 2010	X		X								
Nikkilä et al. 2010	X	X				X	X	X	X	X	X
Sørensen et al. 2010	X	X					X				X
Magne et al. 2010	X										
Sørensen et al. 2011	X										
Robbemond & Kruize 2011	X		X			X					
Allen & Wolfert 2011	X	X			X		X	X		X	
Khaydarov et al. 2012	X										
Yan-e 2012	X	X	X		X						
Kaloxylos et al. 2012	X	X	X		X	X				X	X
Calri & Canavari 2013	X			X							
Burlacu et al. 2013	X	X			X		X				
Jiang & Zhang 2013	X										
Berger & Hovav 2013	X										
Tsiropoulos et al. 2013	X										
Murakami et al. 2013	X										
Honda et al. 2014	X										
Kaloxylos et al. 2014	X		X						X		
Bligaard 2014	X			X				X			
Cojocaru et al. 2014	X	X			X		X				
Barmpounakis et al. 2015	X	X	X			X		X			
Bojan et al. 2015	X										
Fountas et al. 2015a	X	X							X		X
Novkovic et al. 2015	X										
Fountas et al. 2015b	X			X							
Tsiropoulos & Fountas 2015	X										
Kruize et al. 2016	X					X			X	X	
Chen et al. 2016	X										
Parafaros et al. 2016	X										
Ampatzidis et al. 2016	X			X							
Hewage et al. 2017	X										
López-Riquelme et al. 2017	X		X								
Parafaros et al. 2017	X										
Tsiropoulos et al. 2017	X	X		X	X						
Zheleva et al. 2017	X										
Total	38	10	7	6	6	5	5	4	4	4	4

S1	Farmer
S2	Governmental
S3	Agricultural expert
S4	Farm employee
S5	Research institute
S6	FMIS developer
S7	Input supplier
S8	Agricultural advisor
S9	Agricultural service provider
S10	Contractor
S11	Equipment producer

Table 8
The characteristics per identified FMIS. Study ID corresponds to the 38 primary studies presented in Table 4.

Study ID	Name of FMIS	Domain	Modeling approach	Software Type	FMIS type	Software license
Zheleva et al. (2017)	FARMnet	Multipurpose	Box & Lines	Application	x	Academic
Kjær (2008)	Kilo	General	Box & Lines	Application	Desktop, Web, Mobile	Academic
Honda et al. (2014)	Fieldtouch	Arable	Box & Lines	Platform	Web	Academic
López-Riquelme et al. (2017)	WIDHOC	Arable	Box & Lines	Application	Web	Commercial
Voulodimos et al. (2010)	FARMA	Livestock	Box & Lines	Application	Mobile	Academic
Murakami et al. (2013)	Ifarm	Arable	No diagram	Application	Web, Mobile	Academic
Paraforos et al. (2017) & Paraforos et al. (2016)	Ifarma	Arable	Box & Lines	Application	Web, Mobile	Commercial
Berger and Hovav (2013)	Afimilk	Livestock	No diagram	Platform	Desktop, Web	Commercial
Bligaard and Online (2014)	Mark online	Multipurpose	Box & Lines	Application	Desktop, Web, Mobile	Commercial

- Financial management: Is defined out of the sub-features coming directly from the studies like making a billing plan, financial analysis, financial planning, calculate economic results, and budgeting.
- Reporting: Consists of sub-features coming from the data synthesis like documentation generation, report making, and automation of filling in documents. This feature occurs over multiple domains.
- Data Acquisition: Is described as the collecting of data coming from the farm. Also occurs over multiple domains.
- Operation plan generation: Making a plan about how the farm will be managed regarding its strategy and execution. Occurs over multiple domains and is a very general, broad term.
- Crop management: The selection of crops, getting information from the crops, checking the quality of the crops and more crop related sub-features.
- Resource management: The process of using the companies resources as efficient as possible. This feature is mainly present in studies that describe FMIS in general.
- Equipment management: Includes all sub-features that relate to the equipment on the farm like tractors, implements, and other machinery.
- Field monitoring: Mainly occurs in the domain of arable farming. Consists of sub-features that monitor the farmland status and their parameters.
- Data processing: Occurs over multiple domains. Makes sure raw data is converted into useful information for farmers.
- Fertilization management: Everything that has to do with the fertilization of the fields, like determining the fertilizing frame, making a fertilizing plan and the tracking of fertilizers. Occurs mainly in the arable farming domain.
- Human resource management: The management of labor, its main goal is to improve the performance of the employees.
- Weather service: Includes all sub-features related to the weather; weather forecasting, climate forecasting, and information about the previous weather.
- Data management: Includes all the sub-features that deal with data or are controlling data.
- Field management: The field operation management and field-specific management.
- Accounting: The recording of transactions and the keeping of financial records.
- Inventory management: The management of the inventory and stock.

The features and their corresponding studies are presented in Table 9. If we have a look at the features, we see that those occurring the most are those that appear over multiple domains, and more domain specific features appear less. We see that the Financial management feature occurs the most, this was expected since this feature is frequently a central part of FMIS. The other frequently appearing features like Reporting, Data acquisition, Operation plan generation, Resource management, Equipment management, and Data processing also occur over multiple domains and play a central role in the FMIS. Since the arable farming is the most dominant domain in our study, we see that features related to this domain, for example Crop management, Field monitoring, and Fertilization management, appear in the list of Table 9. We furthermore see that there were no studies that describe all of the sixteen most mentioned features.

4.4. RQ3: What are the obstacles to existing FMISs?

In total, we identified 53 obstacles from the primary studies. The obstacles appearing three times or more are described below. The description is based on the definitions given in the primary studies. A table with all 53 obstacles is presented in descending order of frequency occurrence in Appendix C.

- Standardized data formats: Causes problems with the interoperability between different systems and components.
- System integration: FMISs and their components do not integrate with each other easily. Results to problems with interchangeability between applications and platforms.
- Adoption rate of FMIS: The adoption of agricultural innovations has multiple drivers, which can be divided in competitive and contingent factors, socio-demographic factors and financial resources (Pierpaoli et al., 2013; Pedersen and Lind, 2015). The adoption of new technologies in agriculture is rarely instantaneous and multiple factors influence the decision-making processes (Dimara and Skuras, 2003) and can therefore be a result of multiple obstacles.
- Cost of FMIS: Farmers find FMISs too expensive, or they are not able to see the profitability potential of an FMIS.
- Incomplete FMIS: Multiple FMISs are specialized for one specific task on the farm. However, these systems are therefore missing features that will cause the farmer to use multiple FMISs, instead of one FMIS that can provide in all needs.
- Understandability: Current FMISs are not always easy to understand and use for farmers, due to difficult user interfaces or other factors that make them complex.
- Data size: The accumulation of data over the years is seen as a concern
- Connection to internet: Some FMISs are only accessible with an active internet connection; this connection is however not always reliable in more rural areas.
- Insufficient farmer skills: Farmers frequently have a low level of education, and therefore farmers are not always able to obtain the full potential of FMISs.
- Language and regional: Sometimes FMISs are only available in one language. Furthermore, there are big regional differences between countries concerning agricultural practices; FMISs can therefore not always foresee in all farmers needs due to these differences.
- Security: There are currently concerns about the security and privacy of the data that is used in the FMIS.

The obstacles and their corresponding studies are presented in Table 10. From the primary studies, we see that obstacles relating to the standardized data formats and the subsequent obstacles to system integration are most frequent in the primary studies. Other obstacles that occur frequently are those related to the lower adoption rate of FMIS, lack of required skills, language, and understandability of the system. These four obstacles are directly related to the farmer and can probably be solved by making the FMIS easier to understand for farmers and by making the system available in their language. Another frequently mentioned obstacle is the cost of an FMIS; these are often believed to be too high to be profitable. If costs go down obstacles related to the adoption rate of FMISs will most likely also be solved. Obstacles related to missing features, data size, and security of FMIS could probably be addressed by a new design for FMIS.

5. Discussion

In the following sub-sections, we discuss the results. In Section 5.1 we provide a critical reflection on the results. In Section 5.2 we discuss the results in relation to the related work and in Section 5.3 we discuss the threats to validity of the present study and how we tried to address them.

Table 9
The features that occur seven times or more in the primary studies. The name of the feature in the table is not necessarily the name of the feature in the primary study due to the data synthesis step mentioned in Section 3.6.

	Feature categories															
Study	**F1**	**F2**	**F3**	**F4**	**F5**	**F6**	**F7**	**F8**	**F9**	**F10**	**F11**	**F12**	**F13**	**F14**	**F15**	**F16**
Kjær 2008			X													
Voulodimos et al. 2010																
Li et al. 2010					X					X			X			
Yu & Yongjun 2010	X	X			X							X		X		
Nikkilä et al. 2010	X						X			X		X			X	
Sørensen et al. 2010		X	X	X					X							
Magne et al. 2010																
Sørensen et al. 2011	X	X	X	X			X	X	X	X		X	X			X
Robbemond & Kruize 2011	X				X	X					X				X	X
Allen & Wolfert 2011	X					X				X	X			X		X
Khaydarov et al. 2012				X	X					X						
Yan-e 2012	X		X		X											
Kaloxylos et al. 2012			X		X		X		X			X			X	
Calri & Canavari 2013	X	X	X		X		X		X						X	
Burlacu et al. 2013		X	X	X		X		X				X				
Jiang & Zhang 2013			X				X									
Berger & Hovav 2013																
Tsiropoulos et al. 2013			X						X				X			
Murakami et al. 2013	X	X											X	X	X	
Honda et al. 2014								X		X		X			X	
Kaloxylos et al. 2014		X	X	X				X	X			X				
Bligaard 2014	X	X		X		X	X			X	X			X		
Cojocaru et al. 2014	X		X	X				X		X						
Barmpounakis et al. 2015									X				X			
Bojan et al. 2015									X							
Fountas et al. 2015a	X	X				X	X				X			X	X	X
Novkovic et al. 2015					X											
Fountas et al. 2015b	X			X	X		X	X						X		X
Tsiropoulos & Fountas 2015	X	X	X	X												X
Kruize et al. 2016																
Chen et al. 2016																X
Parafaros et al. 2016	X							X								
Ampatzidis et al. 2016	X	X														
Hewage et al. 2017		X	X			X										
López-Riquelme et al. 2017		X			X			X					X			
Parafaros et al. 2017	X			X		X				X	X					
Tsiropoulos et al. 2017	X	X				X	X				X			X		
Zheleva et al. 2017						X		X	X		X		X			
Total	17	14	13	10	10	9	9	9	9	8	7	7	7	7	7	7

F1	Financial management
F2	Reporting
F3	Data aquisition
F4	Operation plan generation
F5	Crop management
F6	Resource management
F7	Equipment management
F8	Field monitoring
F9	Data processing
F10	Fertilization management
F11	Human resource management
F12	Weather service
F13	Data management
F14	Field management
F15	Accounting
F16	Inventory management

5.1. Critical reflection on the results

To the best of our knowledge, this study represents the first systematic literature search on FMISs and thereby aims to pave the way for similar studies on FMISs. In this respect, we identified more than one thousand papers from which we identified 38 high quality primary studies. From the results, we can identify several interesting observations. Over the past eight years a stable number of high quality papers have been published on the features and obstacles of FMIS (see Fig. 3), whereby the focus has been on arable farming or general purpose FMIS (i.e., not focusing on any specific agricultural domain, see Fig. 4). The fact that we were not able to identify FMISs for agricultural domains other than the five we identified might indicate that these domains are not explicitly described in the literature. Although there seems to be a large interest in presenting the architectural designs of FMISs, most of the presented architectural designs are described using informal boxes-and-lines drawings (see Fig. 5, Table 5). The designs consist of various designs from different perspectives, often referred to as views (ISO/IEC/IEEE, 2011). In the reviewed literature, we could identify some explicitly described views, such as the data views (using E-R, data flow

Table 10
The obstacles that occur three times or more in the primary studies. The name of the obstacle in the table is not necessarily the name of the obstacle in the primary study due to the data synthesis step mentioned in Section 3.6.

	Obstacle Categories										
Study	**O1**	**O2**	**O3**	**O4**	**O5**	**O6**	**O7**	**O8**	**O9**	**O10**	**O11**
Kjær 2008	X	X									
Voulodimos et al. 2010											
Li et al. 2010				X						X	
Yu & Yongjun 2010											
Nikkilä et al. 2010	X		X		X	X	X	X		X	
Sørensen et al. 2010		X				X					
Magne et al. 2010						X					
Sørensen et al. 2011		X		X							
Robbemond & Kruize 2011					X						
Allen & Wolfert 2011		X		X				X	X		X
Khaydarov et al. 2012											
Yan-e 2012	X		X			X					
Kaloxylos et al. 2012											X
Calri & Canavari 2013											
Burlacu et al. 2013		X	X								
Jiang & Zhang 2013											
Berger & Hovav 2013			X		X						
Tsiropoulos et al. 2013											
Murakami et al. 2013				X							
Honda et al. 2014											
Kaloxylos et al. 2014				X					X		
Bligaard 2014	X										
Cojocaru et al. 2014		X									
Barmpounakis et al. 2015					X						
Bojan et al. 2015							X				
Fountas et al. 2015a	X	X		X	X		X				
Novkovic et al. 2015									X		
Fountas et al. 2015b	X	X	X								
Tsiropoulos & Fountas 2015			X								
Kruize et al. 2016	X	X					X			X	
Chen et al. 2016											
Parafaros et al. 2016											
Ampatzidis et al. 2016											
Hewage et al. 2017	X					X					
López-Riquelme et al. 2017	X						X				
Parafaros et al. 2017						X					
Tsiropoulos et al. 2017			X		X	X					
Zheleva et al. 2017				X	X			X			X
Total	9	9	7	7	7	7	5	3	3	3	3

O1	Standardized data formats
O2	System Integration
O3	Adoption rate of FMIS
O4	Cost of FMIS
O5	Incomplete FMIS
O6	Understandability
O7	Data size
O8	Connection to internet
O9	Insufficient farmer skills
O10	Language and regional
O11	Security

models), component-and-connector views (using class diagrams) and deployment views (using deployment diagrams). Clements and Bass (2010) documents many more relevant architectural views that are relevant for describing FMISs formally. Based on our results we can state that there seems to be an obvious lack of knowledge on the architecture frameworks that have been provided in the software architecture design community.

We also made interesting discoveries about the software delivery methods. Most of the FMISs we reviewed seemed to be web applications while desktop applications were not explicitly named. This might indicate that a shift is happening from the classic desktop application towards web applications. Most of the FMISs seemed to be application software (as opposed to software platforms) with a predefined set of features, which are not easily extensible. Thus, there seemed to be less focus on a generic and reusable platform software enabling the development of a broader set of applications. Given the broader interest in various domains of FMISs, the focus on generic FMIS platforms could be an interesting research direction. Not surprisingly, the frequently identified FMIS stakeholder was the farmer, followed by the governmental stakeholder.

When analyzing various systems usually both common and variant features can be identified. For the identified FMISs we could observe that some features seemed to be common, indicating the similarity of these FMISs. These common features are generally generic MIS features (e.g., financial management, reporting, and data acquisition) and not specifically related to agriculture. Besides these common generic features, we could also identify several features that do not appear in most FMISs and tend to be variant and specific for some FMISs. We could identify fifty-one obstacles among which we described eleven frequently mentioned obstacles in detail. Some obstacles were very obvious, like system integration and cost of FMIS. Other identified obstacles were less obvious, like the low level of understandability of FMISs, and the lack of required skills by the primary user of the FMISs. No study was identified that described all eleven most occurring features.

5.2. Relation to the related work

The main difference of our study with the related work is that we have explicitly adopted a systematic literature review protocol that is widely accepted and used in the information systems and software engineering community. Based on the SLR protocol, we have searched and identified the FMISs from a broad set of (more than 1000) studies from which we selected 38 primary studies.

Interestingly, our results show that some FMISs that are widely used in practice (e.g., Agworld, FarmWorks or 365FarmNet) have not been documented in the literature. Hence, these were also not covered in our SLR. This indicates that there is a gap between the FMISs that are widely used in practice and the FMISs that were the focus of research. If we compare the identified FMIS features with the features mentioned in the related work (see Section 2), we observe overlap. Although features are sometimes differently named, we can almost always put the functions of FMISs from the related work into one of our identified features. Only the functions Site specific (Fountas et al., 2015a), Quality assurance (Fountas et al., 2015a; Robbemond and Kruize, 2011), and Barcoding/ RFID (Capterra, 2018) could not be captured in any of our identified features since these do not fulfill the concept of a feature as used in this study. For this study, we only used input from the scientific literature. However, if we would have used gray literature (software specifications, web articles, etcetera), we might have had a different result.

5.3. Addressing threats to validity

The most important threats to the validity of an SLR study are publication and selection bias, data extraction, and classification (Dybå and Dingsøyr, 2008). The publication bias is the phenomenon that authors are more likely to publish the positive results rather than the negative results of their research (Kitchenham et al., 2009). We believe we covered the threat of publication bias by applying the study quality assessment, which allowed for the exclusion of five low quality papers that did not present negative findings. The threat of selection bias was covered by defining the study inclusion/exclusion criteria after screening a selection of the primary studies. All selection criteria were discussed among the co-authors to ensure their quality. The validity of the data extraction is important; this directly influences the result of this study. To validate the extraction process, two other persons also did the data extraction for respectively three and four papers. There were small differences in the extracted data; these differences were used to improve the data extraction form. We identified that the extracted data covered the research questions. However, obstacles and features can have sub-categories which could be seen as individual features or obstacles. The data synthesis was, however, performed as objective as possible with the primary goal of keeping as much distinction between the concepts as possible. If there was some uncertainty about the synthesis, the original article was used as a reference.

With the help of our study selection criteria, we were able to exclude all papers that did not relate to the goal of this study. There is, however, always the chance that interesting papers were missed after applying the exclusion criteria, but with a total amount of 38 included papers, we believe we have found a reasonable amount of input data for this secondary study. With the measures presented, we believe we have tackled the main threats for this review.

6. Conclusion

In this study, we have systematically searched the scientific literature of the past eleven years to identify the features and obstacles of FMISs. To the best of our knowledge, this is the first SLR of its kind and the first to review obstacles to FMIS. Our choice to adopt an SLR as an instrument to answer our key research questions appeared to be very useful and led us to the important insights that could be of benefit for both practitioners and researchers. We identified that the FMISs consisted of a combination of some features from the 81 identified features, of which the Financial Management and Reporting features were the most dominant. These two most occurring features are interestingly not directly related to agriculture. We furthermore identified that the FMIS faces a big set of obstacles. In total, we identified a set of 53 obstacles, of which the obstacles related to the standardized data formats and system integration were the most occurring obstacles.

This study has led to novel insights into the current literature of FMIS. First of all, we could identify broad interest in reporting about FMISs. We could indeed identify multiple FMISs that cover a broad range of application domains in the agriculture sector. We could identify multiple different features that define the FMISs. However, from our study, it becomes evident that the notion of architecture design and knowledge of modeling information systems can be considered weak. From the majority of the studies we observe that there is a lack of knowledge among FMIS researchers about the current architecture frameworks that distinguish multiple views for representing architectures from various stakeholder concern perspectives. We believe that many concepts and techniques can be adopted from the software architecture domain.

Another important conclusion is that some widely used FMISs are not reported at all in the literature. A more in-depth and systematic study of these commercial FMISs could further enhance the insight in the development of FMIS and the related benefits and obstacles. The obstacles that we identified were not aimed to criticize the existing FMISs but rather to pave the way for further maturation of the FMISs. We believe that the results of this SLR, as such, is interesting for both researchers that research FMISs and practitioners that aim to develop FMISs. Researchers can identify the key research directions, and practitioners can benefit from the results of this study by a thorough knowledge of the potential features and the possible obstacles. Our future work will include the creation of a new reference architecture for FMIS based on the identified features and obstacles from this study.

Appendix A. Data extraction form

See Fig. 9.

#	*Extraction Element*	*Contents*
General Information		
1	ID	
2	Title	
3	Date of extraction	
4	Year	
5	Authors	
6	Repository	
7	Type	☐ Journal ☐ Article ☐ Book Chapter
8	SLR Category	☐ Include ☐ Exclude
Description		
9	Targeted Domain	
10	Motivation for Study	
11	Main theme of study	
12	Findings	
13	Assessment Approach	☐ Case study ☐ Short example ☐ Experiment
14	Software execution domain	☐ Desktop application ☐ Server application ☐ Plug-in ☐ Web application ☐ Mobile application ☐ Cloud based
15	Name of FMIS	
16	Software architecture described?	No/Yes: ☐ Deployment view ☐ Decomposition view ☐ Other view: ☐ Box and lines ☐ Not about FMIS
17	Software license	☐ Proprietary freeware ☐ Commercial ☐ Open-source ☐ Academic version ☐ Reference design
18	Programming language	
19	Identified Stakeholders	
20	Used database	
21	Constraints/limitations	
22	Evidence Type	☐ Industrial case ☐ Academic case ☐ Academic experiment ☐ Industrial experiment
23	Identified Obstacles	
24	Identified Features	
25	Identified Modules	
Evaluation		
26	Personal note	
27	Additional notes	
28	Quality Assessment	Q1: Q2: Q3: Q4: Q5: Q6: Q7: Q8: tot:

Fig. 9. The data extraction form used in this SLR.

Appendix B. Feature table

See Table 11.

Table 11
Identified Features in descending order.

Financial management	17	Expert knowledge	5	Transport management	2
Reporting	14	Livestock management	5	Calibration management	2
Data aquisition	13	Sales	5	Experience management	2
Operation plan generation	10	Harvest management	4	Marketing and sales	2
Crop management	10	Machinery tracking	4	Reproductivity management	2
Resource management	9	Pesticide management	4	Weighing management	2
Equipment management	9	Scheduling	4	Best practice	1
Field monitoring	9	Work management	4	Collect produce information	1
Data processing	9	Knowledge management	4	Communication	1
Fertilization management	9	Legal management	4	Condition management	1
Human resource management	7	Activity monitoring	4	Delivery management	1
Weather service	7	Customer management	4	Feed management	1
Data management	7	Alerting	4	Grazing management	1
Field management	7	Production monitoring	3	Herd management	1
Accounting	7	Seed management	3	Printing	1
Inventory management	7	Yield monitoring	3	Real estate management	1
Decision support	6	Parameter monitoring	3	Remote controlling	1
Operation management	6	Data sharing	2	Risk analysis	1
Yield estimation	6	Driver assistance	2	Society management	1
Field mapping	6	Energy management	2	Supply management	1
GIS management	6	Health management	2	Task file management	1
Irrigation management	6	Information search	2	Task supervision	1
Sensor management	6	Model production parameters	2	Vision planning	1
Traceability	6	Performance management	2	B2B Collaboration	1
Data transfer	5	Scenario simulation	2	Company information	1
Data storage	5	Strategic planning	2	Environmental monitoring	1
Disease management	5	Technology management	2	Planting management	1

Appendix C. Obstacle table

See Table 12.

Table 12
Identified obstacles in descending order.

Standardized data formats	9	No standardized solution	2	Lack of interoperability standards	1
System Integration	9	Poor user interface	2	Lack of need for farmer	1
Adaption rate of FMIS	7	Scalability	2	Large input needed	1
Cost of FMIS	7	Time consumption	2	Missing modules	1
FMIS not complete	7	Access to system	1	Model integration	1
Not easy to understand	7	Data accuracy	1	No expert trust	1
Data size	5	Data availability	1	No farmer specific design	1
Connection to internet	3	Data confidentiality	1	No modularity	1
Insufficient farmer skills	3	Data correctness	1	Not applicable in other context	1
Language and regional	3	Data exchange	1	Not service oriented	1
Security	3	Data intensity	1	Performance assurance	1
Availability	2	Data is scattered	1	Privacy	1
Complexity of farms	2	Data management	1	Proprietary system	1
Data complexity	2	Data processing	1	Reliability	1
Data diversity	2	Data timeliness	1	Slow information updating	1
Data integration	2	Early stage of development	1	Too much information	1
Data integrity	2	Knowledge integration	1	Too specialized	1
Different interfaces	2	Lack of information standards	1		

Appendix D. Supplementary material

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.compag.2018.12.044.

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