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Management information system adoption at the farm level: evidence from the literature

Carlo Giua
Department of Agricultural and Food Sciences, Alma Mater Studiorum - Università di Bologna, Bologna, Italy
Valentina Cristiana Materia
Department of Social Sciences, Business Management and Organisation Group, Wageningen University and Research, Wageningen, The Netherlands, and
Luca Camanzi
Department of Agricultural and Food Sciences, Alma Mater Studiorum - Università di Bologna, Bologna, Italy

Abstract

Purpose – This paper reviews the academic contributions that have emerged to date on the broad definition of farm-level management information systems (MISs). The purpose is twofold: (1) to identify the theories used in the literature to study the adoption of digital technologies and (2) to identify the drivers of and barriers to the adoption of such technologies.

Design/methodology/approach – The literature review was based on a comprehensive review of contributions published in the 1998–2019 period. The search was both automated and manual, browsing through references of works previously found via high-quality digital libraries.

Findings – Diffusion of innovations (DOIs) is the most frequently used theoretical framework in the literature reviewed, though it is often combined with other innovation adoption theories. In addition, farms' and farmers' traits, together with technological features, play a key role in explaining the adoption of these technologies.

Research limitations/implications – So far, research has positioned the determinants of digital technology adoption mainly within the boundaries of the farm.

Practical implications – On the practical level, the extensive determinants' review has potential to serve the aim of policymakers and technology industries, to clearly and thoroughly understand adoption dynamics and elaborate specific strategies to deal with them.

Originality/value – This study's contribution to the existing body of knowledge on the farm-level adoption of digital technologies is twofold: (1) it combines smart farming and existing technologies within the same category of farm-level MIS and (2) it extends the analysis to studies which not only focus directly on adoption but also on software architecture design and development.

Keywords Smart farming, Farm management information systems, Enterprise resource planning, Adoption, Diffusion of innovation, Digital divide

Paper type Literature review

Corrigendum: It has come to our attention that "Management information system adoption at the farm level: evidence from the literature" by Carlo Giua, Valentina Cristiana Materia and Luca Camanzi, published in the *British Food Journal*, [Vol. ahead-of-print No. ahead-of-print, 10.1108/BFJ-05-2020-0420], contained several mistakes within the author affiliations. This has now been corrected in the online article. The authors sincerely apologise for this.

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1. Introduction

Agri-food systems are on the verge of a new *revolution* based on the use of digital innovations throughout the supply chain (Lehmann *et al.*, 2012; Trendov *et al.*, 2019; Wolfert *et al.*, 2017). Scholars have applied different names to define this digitalisation, including "digital agriculture", "agriculture 4.0" and "smart farming". That notwithstanding, there is common agreement on the central role that data play in the agri-food supply chain's virtualisation (Verdouw *et al.*, 2016).

Despite the general agreement on the beneficial effects that this revolution will have for the agri-food system in terms of greater efficiency, effectiveness and sustainability (Fabregas *et al.*, 2019; Lehmann *et al.*, 2012), the process of adopting innovative digital technologies requires resources and competences which not all the actors possess (Poppe and Renwick, 2015). For instance, the literature shows that amongst internal resources, farm size and financial availability can be important barriers to overcome, especially for small and medium enterprises (SMEs) (Bucci *et al.*, 2018; Lawson *et al.*, 2011). Amongst external resources, poor Internet connectivity, data transfer and privacy concerns are just some of the factors reported as obstacles to the adoption process (Kernecker *et al.*, 2019; Pivoto *et al.*, 2019). In addition, not only resources but also specific competences need to be developed by firms – the so-called dynamic capabilities (Teece *et al.*, 2008) – in order to achieve a suitable digital transformation of their business (Bouwman *et al.*, 2018; Warner and Wäger, 2019; Zahra and George, 2002).

Disparities in the process of adopting digital technologies might further aggravate the unequal distribution of value that already exists in certain cases between small–medium (especially in upstream production stages) and large players (downstream production stages, especially distribution and retailers). This is particularly true for the European agri-food productive structure which predominantly comprises SMEs (Capitanio *et al.*, 2009; FoodDrinkEurope, 2016; Materia *et al.*, 2017). Furthermore, the digitalisation process can be quite different depending on the nature of the digital technologies and on the challenges that arise in different supply chain stages (Pivoto *et al.*, 2019; Poppe and Renwick, 2015).

In light of the above considerations, this study aims to provide a more specific systematisation of the factors that enable and hinder the adoption of different technologies.

To this end, this research focusses specifically on the farm-level adoption of smart-farming solutions since the digitalisation of the supply chain's upstream stage is an essential condition to successfully exploit this revolution and ensure that all stakeholders benefit. Indeed, farmers (particularly in small and medium agri-food enterprises) have traditionally been reluctant to innovate (Long *et al.*, 2016) and they often lack the required resources and competences, especially for human capital-intensive innovations (Dicecca *et al.*, 2016; Materia *et al.*, 2017; Warren, 2002).

The study is based on a comprehensive review of contributions from the scientific literature dealing with the adoption of farm-level digital innovations, with a specific focus on management information system (MIS) technologies, defined as a set of software systems used to support human decision-making within farm management activities (Fountas *et al.*, 2015a; Verdouw *et al.*, 2015). This study reviews the theoretical frameworks used as well as the drivers and barriers, both within and beyond farm boundaries.

The paper is structured as follows: section 2 sets out the scope and the objective of the study by means of providing a definition of the technologies considered and presenting the research questions. Section 3 outlines the methodology and discusses the sources of literature considered. Section 4 describes the main results, including descriptive characteristics and evidence gathered concerning the theoretical frameworks adopted and main evidence found in the literature reviewed. Finally, section 5 includes a discussion of these findings together with some recommendations for future research.

2. The scope and objectives

2.1 Management information systems at the farm level

In recent years, a large number of digital technologies have become available for actors in upstream stages within agri-food chains. Amongst these, advanced decision support systems (DSSs) have garnered increasing attention, enabling farmers to make informed decisions not only related to farming practices (precision agriculture technologies) but also financial and managerial operations (Fountas *et al.*, 2015a).

Amongst such software solutions, scholars have placed particular focus on the farm management and information systems (FMISs) category. Sørensen *et al.* (2010, p. 38) defined FMISs as "a planned system for the collecting, processing, storing and disseminating of data in the form of information needed to carry out the functions of the farm". In addition, they point out that FMISs can be considered "an integral part of the overall management system of a firm [. . .] and part of tools such as Enterprise Resource Planning (ERP) and overall Information Systems (IS)" (Sørensen *et al.*, 2010, p. 38). By contrast, ERP technologies are defined as standardised software packages which incorporate information systems for multiple business functions to create a single integrated system (Verdouw *et al.*, 2015).

In fact, even if FMIS and ERP applications have followed different evolutionary paths, today they communicate and collaborate within agri-food enterprises' information technology (IT) systems. On the one hand, modern FMISs were developed to organise the increasing amount of data generated by precision agriculture technologies and combined them with an economic and holistic management perspective (Fountas *et al.*, 2015a; Verdouw *et al.*, 2015). On the other hand, ERPs stem from manufacturing resource planning systems and the necessity to integrate both across and within the various functional silos found in modern manufacturing (Jacobs and Weston, 2007). Initially, the rigid standards of early ERP solutions were not well suited to deal with the complexity of agricultural biological processes. Nonetheless, new web-based and customisable ERP systems are much more flexible (Møller, 2005) and capable of ensuring the interoperability required to integrate "many FMISs, DSSs and many applications in between, all covering different aspects of farm management" (Verdouw *et al.*, 2015, p. 127).

This is why various authors argue that integrating FMIS and ERP research can result in numerous and promising research opportunities that are worth investigating (Haberli *et al.*, 2019; Verdouw *et al.*, 2015).

Hence, for the purposes of the present study, the literature analysed includes research conducted on the farm-level adoption of both FMIS and ERP as well as the intersections between these two technologies. Given the fast-developing nature of digital technologies, by including contributions dealing with different versions of FMIS (both computer- and mobile-based systems, applications, software as a service [SaaS], etc.), this review provides the opportunity to consider as many different contributions to the topic as possible. In the rest of the paper, the term "farm-level MIS" refers to this combined group of management information technologies.

2.2 Research questions

The literature on the farm-level adoption of MIS has mostly focussed on FMIS technologies. To the best of the authors' knowledge, the first specific contribution dates back to the end of last century (Lewis, 1998). At that time, the technical characteristics and functionalities of software and devices used were more akin to computers assisting agricultural production as compared to how FMISs are used today (Tummers *et al.*, 2019). Amongst most recent contributions, Tummers *et al.* (2019) reviewed the obstacles to FMIS development and adoption found in the literature, besides providing a more updated state of the art on device functionalities. Amongst these barriers, some are more related to technical traits such as data standards and system integration, while others relate more specifically to factors linked to lower adoption, such as the comprehensibility of software, insufficient skills amongst farmers and regional/language barriers.

Although Tummers *et al.* (2019) referred to specific obstacles, FMIS adoption has been analysed only partially to determine the explanatory variables behind their diffusion, not as the actual object of study. In fact, to the best of the authors' knowledge, the available literature still lacks a review which focusses specifically on farm-level MIS adoption processes.

This paper thus aims to fill this research gap, identifying the drivers and barriers behind the adoption of these technologies. In order to effectively summarise and contextualise these determinants, this study also analyses the theoretical frameworks used in the literature, the aim being to understand which theoretical lenses scholars have used to identify adoption factors to date. Consequently, this study proposes the following research questions:

RQ1. Which theories have scholars used to study the adoption of farm-level MISs?

RQ2. What are the main determinants affecting the adoption of farm-level MISs?

RQ2.1. What are the main drivers?

RQ2.2. What are the main barriers?

3. Materials and methods

The process of searching, collecting, selecting and synthesising literature occurred between September 2019 and January 2020, following the literature review's approach proposed by Hart, who defined it as "the selection of available documents (both published and unpublished) on the topic, (. . .) to fulfil certain aims or express certain views on the nature of the topic and how it is to be investigated, and the effective evaluation of these documents in relation to the research being proposed" (Hart, 1998, p. 13).

This approach has been integrated with both specific guidelines on how to structure the review (Torraco, 2005; Vom Brocke *et al.*, 2009) and existing examples of structured literature reviews (Boehm and Thomas, 2013; Cronin *et al.*, 2008; Della Corte *et al.*, 2018; Giacomarra *et al.*, 2020; Svejvig and Andersen, 2015; Tell *et al.*, 2016), with the aim to clearly present the analysis and results. Therefore, the review is organised in the following three phases: (1) search strategy, (2) screening and selection and (3) data extraction and analysis.

3.1 The search strategy

The automated research component implied using two of the key high-quality digital libraries available: the Institute for Scientific Information (ISI) Web of Science and Scopus. As recommended by Hart (1998), after different attempts to identify the most inclusive string, the final research query combined various sets of keywords such as farm MISs, FMISs, ERP and adoption. Search results included journal articles, conference papers and proceedings, white papers, reports and book sections, all published in English as found in the most recent FMIS review carried out by Tummers *et al.* (2019). In order to take the technological evolution of these management systems into account while also being aware of the quickly developing literature on IT in agriculture, texts were limited to the 1998–2019 period, starting from the first review on FMIS available in these sources (Lewis, 1998). This search identified additional studies that were then added to the screening process through snowball techniques. The authors identified these additional texts by manually browsing through references of works previously found via the automated search. A preliminary refinement of articles was based on selecting Web of Science categories pertaining to agricultural economics and policy, agriculture multidisciplinary, computer science interdisciplinary applications and management. A total of 849 studies were identified in these digital libraries (576 from ISI WOS and 273 from Scopus). An initial selection was carried out before downloading the studies, based on their titles and reading their abstracts. In this stage, the authors considered each contribution related to FMIS design, use and adoption and ERP adoption at the farm level for further refinement. A final screened sample of 70 studies was downloaded from said digital libraries (35 from ISI WOS and 35 from Scopus).

3.2 Screening and selection

All the studies identified were imported into a single library and processed using Mendeley citation manager software. Using the "Check for duplicates" feature, 12 studies were deleted, reducing the number of papers retained for analysis to 58. The screening selection process was based on two steps as found in Giacomarra *et al.* (2020). First, the authors established the following inclusion criteria: (1) all studies which focussed on FMISs (computer- or mobile-based) and ERP adoption used in the agri-food sector and (2) all studies which focussed on FMIS design, development and technological evolutions (traceability, big data, cross compliance and cloud-based platforms). A total of nine additional studies were eliminated as a result of the previous step. Second, studies were further screened based on the exclusion criteria listed in Table 1 below.

The final subset included 35 studies for analysis and study (see Figure 1 below). The authors could not access the full text of one study due to licence restrictions and had to eliminate it from the sample. Moreover, 22 other studies did not satisfy the exclusion criteria indicated above, while additional nine works were eventually added to the final selection by browsing references of selected studies.

At this step, the authors did not only consider academic contributions which focussed solely on adoption. They expanded the scope to focus on other types of studies dedicated to FMIS software design and development. This choice was made for several reasons. First, one deals with the user-centric approach found in several texts (Kaloxylos *et al.*, 2012; Kruize *et al.*, 2016; Sørensen *et al.*, 2011), an approach which "assumes that the users' ideas and

Table 1.
Second-step selection criteria

Number of exclusion criteria	Criteria description
Criterion 1	Studies indicating an adoption theoretical framework
Criterion 2	Studies focussed on farm management information system (FMIS) design and users
Criterion 3	Studies considering adoption process drivers and barriers

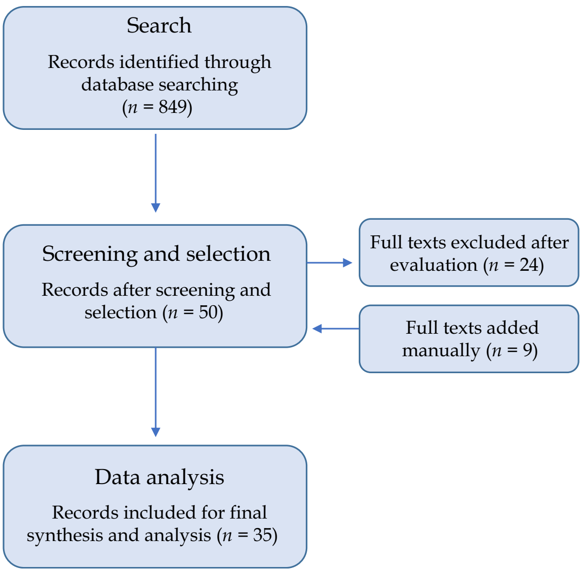

Figure 1.
Flow diagram of the review process

requirements reactions concerning the speciffc characteristics of the designed technology are integrated in the subsequent design" (Sorensen *et al.*, 2010, p. 45). As several scholars acknowledge, end-user involvement during the early stage of the devices' design and development makes it easier to satisfy user requirements and, as a result, make user acceptance and adoption more likely. An example of this approach is found in Nurkka *et al.* (2007), where data from interviews, questionnaires and farms visits served to identify users' needs, demands and capabilities before designing a specific MIS, recognising, at the same time, problems and limitations that might occur in the adoption and use of such devices.

In addition, considering actual technology adoption and design simultaneously allows for a more complete picture on adoption determinants, including factors which might not be attributable solely to the adopter. This way, a more thorough understanding is possible, though not only of technology adoption, *per se*, but also some of its disparate consequences, one of which is the digital divide in the agri-food sector (Bronson and Knezevic, 2016; Trendov *et al.*, 2019). This refers to the situation in which a substantial proportion of the population, identified by one or more shared characteristics, lags significantly behind others in the adoption of a new technology (Warren, 2002). Indeed, as Bronson (2019, p. 3) argues that "The bifurcation in the market for smart farming technologies may not simply be an adoption issue beginning on the farm (and with farmers); rather, it at least partly results from partial and normatively motivated design decisions which are helping to produce digital farming 'haves' and 'have-nots'". For these reasons, this paper includes various types of studies (both qualitative–descriptive and quantitative–deterministic), with the aim being to capture all the different determinants of farm-level MIS adoption identified until now.

3.3 Data extraction and the analysis

The authors uploaded all 35 papers to the ATLAS.ti 8 platform, a widely used piece of software to undertake qualitative data analyses and literature reviews (Haan *et al.*, 2018; Hossain, 2016; Hossain *et al.*, 2019). The authors read the selected studies thoroughly and coded them with references to an extraction form organised in a matrix structure as suggested by Finfgeld-Connett (2014) and Leonidou *et al.* (2018), with the aim to "minimize human error and document this procedure for replicability purposes" (Leonidou *et al.*, 2018, p. 3) . The matrix's structure is based on (1) research questions for the literature review in keeping with Hart's recommendations (1998), (2) the data extraction method used by previous literature reviews to classify FMISs (Tummers *et al.*, 2019) and (3) the reading of a sample of randomly selected studies to iteratively adjust the structure (Hossain *et al.*, 2019; Tummers *et al.*, 2019).

The initial matrix structure comprised several features with the following classifications: general information (author, title, publication year and type of document), study description (sector, main theme, methods used, stakeholders involved, etc.) and adoption (theoretical framework – if any and including drivers and barriers). During the coding process, the authors created new themes when needed to categorise new codes. Most of the description elements were used to build statistic elaborations on the studies collected and together with the section focussed on adoption, they served to answer the research questions posited.

4. Results

This section summarises the data obtained distributed into two sections, in keeping with the review structures used by Radu (2016) and Tummers *et al.* (2019). The first focusses on descriptive statistics on the composition and main characteristics of the final sample of texts; the second provides findings to answer the research questions outlined above.

Trends regarding the number of publications and the composition of the sample of contributions studied provide interesting insights. The overall number of contributions is rather stable, apart from two peaks registered in 2010–2011 and in 2017 (see Figure 2).

Both peaks denote the academic attention to evolved versions of FMISs with respect to more basic information systems available until that moment. In several cases, these studies may have been encouraged by international research projects (such as the EU-funded FUTUREFARM project or the SmartAgrifood and FiSpace projects, part of the European Future Internet Public–Private Partnership programme (FI-PPP)) [1].

As this paper includes studies with research focusses other than just technology adoption, the authors classified the contributions by the main themes addressed and synthesised the findings into the following key categories: adoption, software design and other types of studies.

The "User adoption studies" category primarily comprises papers focussed specifically on MIS adoption by agri-food users; the "Software design studies" group incorporates contributions that do not focus on adoption, *per se*, but on the development of a software architecture model. As explained above, due to the user-centric approach applied in these papers, the authors of this study were able to identify user requirements and barriers to FMIS adoption and use. Last, the "Other studies" category includes contributions with a broader focus. Some of the texts included in the latter group report on the state of the art of FMIS development and use, along with future perspectives (Allen and Wolfert, 2011; Fountas *et al.*, 2015a; Kuhlmann and Brodersen, 2001; Tsiropoulos *et al.*, 2017). Other contributions focus on the development of integrated platforms (software ecosystems) to make smart-farming technologies (such as FMIS) interoperable (Barmpounakis *et al.*, 2015; Kruize *et al.*, 2016).

In this study, the authors classify the literature according to the type of research conducted (qualitative vs quantitative): 20 studies were classified as qualitative and the remaining 15 as quantitative [2]. Table 2 below shows how all these studies are distributed.

While almost all the qualitative texts are included in the "Software architectural models" and "Other studies" categories, only two of the 15 studies on MIS adoption are qualitative. In the next sections, the authors discuss additional details on adoption studies.

4.1 The oretical and methodological approaches in adoption studies

Studies which focussed specially on farm-level MIS adoption are listed in Table 3 below. A technological evolution occurred in the devices objects of adoption studies, from computer-

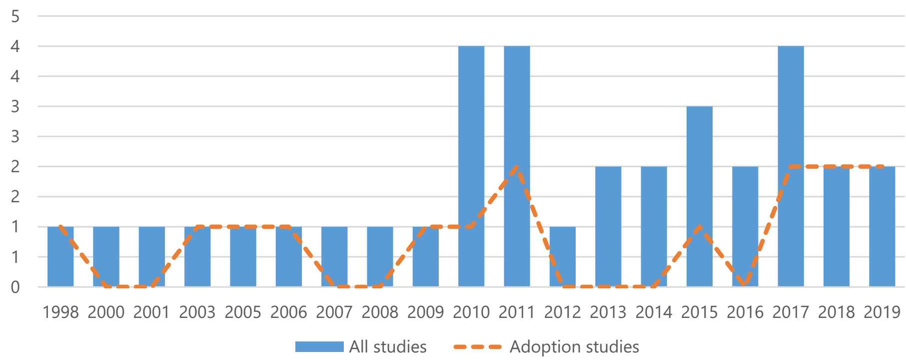

Figure 2.
Time distribution of studies

Table 2.
Thetype of research (qualitative or quantitative) by research focus

	Qualitative	Quantitative	Total
User adoption	2	13	15
Software design	13	1	14
Others	5	1	6
Total	20	15	35

Table 3. Studies focussed on adoption

Authors	Title	Year	Source	Type of study	Theory	Methodology	Scope	Publication findings
Lewis	Evolution of farm management information systems	1998	*Computers and Electronics in Agriculture*	Paper	DOI; Scheuing model (1989)	Quantitative, OLS regression	The study provides a description of FMISs' technological evolution and identifies factors associated with the use of these increasingly sophisticated technologies	On average, use of sophisticated FMIS depends on individuals' characteristics (age and education) and common business factors (office equipment) rather than factors specific to farming activities
Rosskopf and Wagner	Requirements for agricultural software – results of empirical studies	2003	*European Federation for Information Technology in Agriculture (EFITA)*	Conference paper	–	Quantitative, descriptive statistics	The study investigates the decision process of farmers regarding agricultural software	There are differences in identification of adoption determinants between scientists and IT experts (software's usability and costs) and farmers (lack of training and poor performances, inadequacy incompatibility)
Batte	Changing computer use in agriculture: evidence from Ohio	2005	*Computers and Electronics in Agriculture*	Paper	–	Quantitative, probit model	The study investigates use of computers for farm management amongst farmers from Ohio, the USA	Adoption is more likely to occur amongst younger, more educated farmers, with larger farms and who worked year-around away

(*continued*)

Table 3.

Authors	Title	Year	Source	Type of study	Theory	Methodology	Scope	Publication findings
Alvarez; Nuthall	Adoption of computer based information systems: the case of dairy farmers in Canterbury, NZ, and Florida, Uruguay	2006	*Computers and Electronics in Agriculture*	Paper	DOI; behavioural modelling Kline 1999, Vanclay and Laurence 1995)	Quantitative, structural equation modelling	Authors investigate farmers' information management behaviour in relation to agricultural software's adoption process in both New Zealand and Uruguay	Adoption of computers for farm management depends on both farmers' characteristics (age, education, farm size and information system, time availability) and software features (usability and costs)
Mackrell *et al.*	A qualitative case study on adoption and use of agricultural decision support system in the Australian cotton industry	2009	*Decision Support Systems*	Paper	DOI Orlikowsky model, 2000	Qualitative, in-depth interviews	The study analyses the adoption process of a decision support tool for cotton farm management	Adoption success depends on technology compatibility, possibility to customise it and farmers' time availability
Engler; Toledo	An analysis of factors affecting the adoption of economic and productive data recording methods of Chilean farmers	2010	*Ciencia e Investigation Agraria*	Paper	–	Quantitative, probit model	The paper studies the adoption of digital record-keeping tools by a sample of Chilean farmers	Adoption of digital tools for record keeping is mainly observed in younger, educated, risk-adverse farmers who lease land and participate to technology's transfer groups

(*continued*)

Authors	Title	Year	Source	Type of study	Theory	Methodology	Scope	Publication findings
Lawson *et al.*	A four nation survey of farm information management and advanced farming systems: a descriptive analysis of survey responses	2011	*Computers and Electronics in Agriculture*	Paper	–	Quantitative, descriptive statistics	The work presents results from a survey on perception of information systems technology by farmers from Finland, Denmark, Germany and Greece	Results indicate that adoption of new farm information system is more likely to be observed in younger and more educated farmers, with larger farms. Nonetheless, majority of respondents from all countries were unsure about benefits of new technologies
Tiffin; Balcombe	The determinants of technology adoption by UK farmers using Bayesian model averaging: the cases of organic production and computer usage	2011	*Australian Journal of Agricultural and Resource Economics*	Paper	–	Quantitative, Bayesian modelling average and probit models	The study investigates technology adoption's determinants (in forms of organic production and use of computers for farm management) in UK farming	Farm's size (in terms of number of workers), education and age of the farmers are the variables which influence the adoption of computers for farm management
Verdouw *et al.*	ERP in agriculture: Lessons learned from the Dutch horticulture	2015	*Computers and Electronics in Agriculture*	Paper	DOI	Qualitative, in-depth interviews	The study analyses ERP adoption in Dutch horticulture industry	Adopters are driven by benefits of this technology and the possibility to customise it, but major obstacles remain in a proper management for the implementation, together with the complexity and costs of the technology

(*continued*)

Table 3.

Table 3.

Authors	Title	Year	Source	Type of study	Theory	Methodology	Scope	Publication findings
Carrer *et al.*	Factors influencing the adoption of Farm Management Information Systems by Brazilian citrus farmers	2017	*Computers and Electronics in Agriculture*	Paper	Microeconomic theory	Quantitative, logit and Poisson models	The study investigates adoption of farm management information systems in the Brazilian citrus sector	Adoption is positively linked to production revenue of farms, technical assistance received and farmers' level of education and management confidence. Conversely, farmers' experience and contractual adjustments were negative factors
Haberli *et al.*	Understanding the determinants of adoption of enterprise resource planning (ERP) technology within the agri-food context: the case of the Midwest of Brazil	2017	*International Food and Agribusiness Management Review*	Paper	DOI TOE	Quantitative, structural equation modelling	The study analyses ERP's adoption determinants in Brazilian soy, corn and cotton sector	It is found that adoption rate is positively affected by technology's relative advantage, farms' size, management support and technology readiness, while is hampered by complexity in usage
Fox *et al.*	Towards an understanding of farmers' mobile technology adoption: A comparison of adoption and continuance intentions	2018	*Americas Conference on Information Systems 2018*	Paper	UTAUT	Quantitative, structural equation modelling	The study investigates adoption and use of farm management mobile-based technologies amongst both non-users and users	Non-users are most likely to adopt the application when recommended by a peer; users' intention to continue to use is driven by usability and usefulness

(*continued*)

Authors	Title	Year	Source	Type of study	Theory	Methodology	Scope	Publication findings
Ibrahim *et al.*	Factors Influencing Acceptance and Use of ICT Innovations by Agribusinesses	2018	*Journal of Global Information Management*	Paper	UTAUT	Quantitative, structural equation modelling	The study analyses what factors influence adoption of ICTs by small and medium agribusinesses	Results indicate that on five hypothesised predictors, only performance expectancy, management characteristics and organisational size are found to positively influence adoption
Haberli *et al.*	The adoption stages (Evaluation, Adoption, and Routinisation) of ERP systems with business analytics functionality in the context of farms	2019	*Computers and Electronics in Agriculture*	Paper	DOI, TOE and interorganisational relations (IORs) theory	Quantitative, structural equation modelling	The study carries out a both qualitative and quantitative study which investigates determinants of ERPs' diffusion in Brazilian agriculture	Relative advantage, compatibility and right technological environment within the agribusinesses are found to be significant predictors of adoption
Pivoto *et al.*	Factors influencing the adoption of smart farming by Brazilian grain farmers	2019	*International Food and Agribusiness Management Review*	Paper	Microeconomic theory	Quantitative Poisson model	The study investigates adoption's determinants of smart-farming technologies by Brazilian farmers	For what concerns farm management software, handling time was perceived as a barrier, while benefits related to farm management and costs together with farm size were the drivers

Table 3.

based management information systems (Alvarez and Nuthall, 2006; Batte, 2005; Lewis, 1998; Tiffin and Balcombe, 2011) to more sophisticated, application-based and Internet-connected versions (Carrer *et al.*, 2017; Fox *et al.*, 2018; Pivoto *et al.*, 2019). A total of three papers focussed on ERP adoption at the farm level (Haberli *et al.*, 2017, 2019; Verdouw *et al.*, 2016). The authors checked the technological coherence of this software with FMISs (discussed above) during the first selection step since only contributions that studied ERP as aligned with FMIS were considered in adoption studies.

In terms of theoretical approaches, 11 of the 15 studies in this group used at least one conceptual framework to study technology adoption. The most used theory was the diffusion of innovation (DOI), devised originally by Rogers (2003, 1995). DOI theory studies the spread of innovations and how they proliferate through different channels over time and within a particular social environment. According to Rogers, the innovation–decision process involves five steps: (1) knowledge, (2) persuasion, (3) decision, (4) implementation and (5) confirmation. These stages typically follow each other in a time-ordered manner. Adoption then depends on how individuals might perceive what Rogers (1982) defined as five innovation attributes, i.e. relative advantage, compatibility, complexity, trialability and observability.

Verdouw *et al.* (2015) are the only scholars in this review who used DOI as a unique framework. Also, two studies (Haberli *et al.*, 2017, 2019) integrated DOI with technology–organisation–environment (TOE), another widely used theory in adoption studies (Molinillo and Japutra, 2017; Oliveira and Martins, 2011). The TOE framework identifies the process used by a company to adopt and implement innovations, taking into account the technological, organisational and environmental context (De Pietro *et al.*, 1990). Fox *et al.* (2018) and Ibrahim *et al.* (2018) applied the unified theory of adoption and use of technology (UTAUT). UTAUT integrates eight theories on technology adoption: the technology acceptance model (TAM), the theory of reasoned action (TRA), DOI, the motivational model, the theory of planned behaviour, a combined theory of planned behaviour/ TAM, a model of personal computer use and social cognitive theory.

4.2 Adoption drivers reported in the literature

This section presents the major drivers behind the adoption of farm-level MIS found through the review. To ensure an efficient synthesis, only drivers coded at least four times are reported in this paper (Tables A1 and A2 in the appendix) in keeping with Tummers *et al.* (2019).

Results indicate that the most recurrent drivers are technology usability, farm size and farmer education level. Pignatti *et al.* (2015) categorised FMIS adoption drivers into three different groups: the innovations' technological features, farm and farmer traits and external environment features. This study applies this same classification.

The International Organization for Standardization (ISO) defines usability/ease of use as follows: "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" (Bevan and Carter, 2016, p. 269). This driver can thus be considered part of the 'technological features' category. As found in (Carli and Canavari, 2013; Husemann and Novkovic, 2014; Nikkilä *et al.*, 2010; Rosskopf and Wagner, 2003; Sopegno *et al.*, 2016) and Alvarez and Nuthall (2006), important factors when deciding to adopt a given MIS include user-friendly interfaces and easy-to-use software to input data and retrieve data output from the system. Furthermore, the possibility of customising a farm-level MIS or its flexibility is another driver included in this category. Indeed, when customised technologies meet farms' specific needs while providing standard functionalities, users are more likely to adopt them (Mackrell *et al.*, 2009; Rosskopf and Wagner, 2003).

Another driver category is related to farm characteristics. Farm size – generally measured not only in terms of land extension but also in terms of gross sales in some cases (Batte, 2005) or the number of paid workers (Tiffin and Balcombe, 2011) – is the most recurrent driver. Larger farms have to manage more complex production processes and they need to gather and process more information (e.g. precision agriculture data); therefore, farm-level MIS have to organise management data and control complexity (Carrer *et al.*, 2017; Pivoto *et al.*, 2019). Another driver included in this category is the farm's initial technology, a factor which includes all the different technologies already in use on the farm (current IT systems, other smart-farming technologies, etc.) and which might favour the adoption of a complementary farm-level MIS (Alvarez and Nuthall, 2006; Lewis, 1998).

The third most recurrent driver is farmers' education, included in the user characteristics category. Several studies found that more educated farmers were more likely to adopt MIS (Alvarez and Nuthall, 2006; Carrer *et al.*, 2017; Engler and Toledo, 2010; Kaloxylos *et al.*, 2014; Lewis, 1998; Tiffin and Balcombe, 2011). As explained by Carrer *et al.*: "Farmers with higher education manifest greater demand for information and stronger ability to evaluate the beneffts of using computers as a tool to support management decision-making" (Carrer *et al.*, 2017, p. 16). Another user characteristic which might have a positive influence on adoption is the existing level of IT skills needed to use management systems, including familiarity with computers or information systems (Allen and Wolfert, 2011; Kuhlmann and Brodersen, 2001; Nurkka *et al.*, 2007) and with Internet usage (Kaloxylos *et al.*, 2014). In addition, there are several important factors within this group related to users' beliefs, perceptions and needs which drive farm-level MIS adoption. Amongst the individual perception factors, several studies point to the perceived relative advantage. Rogers defined this as "the degree to which an innovation is perceived as better than the idea it supersedes" (Rogers, 1982, p. 213). In this sense, there are different interconnected subdimensions regarding relative advantages related to farm management: the degree of economic profitability, costs, benefits in terms of time and effort, etc. Haberli *et al.* (2019), Rosskopf and Wagner (2003), Tsiropoulos *et al.* (2017) and Verdouw *et al.* (2015) determined that perceived benefits include greater transparency, greater integration and improved efficiency, as well as expected profitability and other aspects related to the economic dimension of relative advantage.

When only considering studies that specifically focus on adoption, the most recurrent driving factors are limited to farms' and farmers' characteristics, such as size, education and relative advantage. No recurrent drivers were identified in the external environment group of features.

4.3 Adoption barriers reported in the literature

This study applied the same analysis to adoption barriers (see Table A1 in the appendix). When applying the same categorisation to factors which directly or indirectly impede adoption, it seems that technological features are the most relevant barriers.

As Tummers *et al.* (2019) described, problems related to interoperability or system integration between FMISs and their components hinder "interchangeability" between applications and platforms, reducing their applicability and, thus, the future adoption of such technology (Kruize *et al.*, 2016). For Rosskopf and Wagner (2003), an important requirement expressed by some farmers is the possibility of adapting/integrating new and old software. Interoperability issues are strictly connected to data standards since a lack of industry-wide data exchange protocols causes difficulties in data exchange, thus limiting farm-level MIS applicability (Allen and Wolfert, 2011; Fountas *et al.*, 2015a; Kruize *et al.*, 2016). Another aspect related to technological features refers to concerns regarding data ownership, privacy and security, representing issues for users and possible adopters (Allen and Wolfert, 2011; Fountas *et al.*, 2009; Kaloxylos *et al.*, 2014; Zheleva *et al.*, 2017).

Included amongst technological factors which hinder adoption more directly is the complexity of these technologies; this not only includes unintuitive or excessively complicated interfaces but also too many features when compared to users' actual needs, making farm-level MIS technologies difficult to implement, understand and use (Haberli *et al.*, 2017; Nikkilä *et al.*, 2010; Verdouw *et al.*, 2015). This perceived complexity is one of the causes that makes these technologies time-consuming for possible adopters, especially in terms of learning how to use them (Alvarez and Nuthall, 2006; Pivoto *et al.*, 2019), for example, when manually inputting data (Mackrell *et al.*, 2009; Steffe, 2000). These aspects are inversely connected to usability as a driver as discussed in the previous section, underscoring how much software design influences its adoption.

Between the technological feature and farm resource categories, the cost of these technologies certainly plays a role in adoption decisions. For Allen and Wolfert (2011), farmers are reluctant to invest too much in this software due to lower farm profitability and high market volatility. Kaloxylos *et al.* (2014) reported some concerns about the cost of other smart-farming technologies related to their implementation; these can be even more prohibitive in the case of smallholders or SMEs (Zheleva *et al.*, 2017). Finally, when it comes to user characteristics, several studies cite age as a common adoption barrier (Allen and Wolfert, 2011; Alvarez and Nuthall, 2006; Batte, 2005; Fountas *et al.*, 2015b; Lewis, 1998; Tsiropoulos *et al.*, 2017). The common argument is that new generations of farmers are usually more educated and computer skilled, thus more willing to use new technologies. Again, when only considering studies specifically focussed on adoption, age is the most important adoption barrier (Alvarez and Nuthall, 2006; Batte, 2005; Engler and Toledo, 2010; Lewis, 1998; Tiffin and Balcombe, 2011). Interestingly, a limited perception of the benefits of these tools is another recurrent barrier. Indeed, as Rosskopf and Wagner (2003, p. 653) explained that "[...] While the scientists saw the cost of technology and the lack of user friendliness as the main problems, the participants of this study thought that lack of training and failure to understand the possible benefits were the greatest impediments". In fact, cost is not found to be a recurrent barrier in these studies as opposed to their complexity in terms of the time required to assimilate these technologies (Alvarez and Nuthall, 2006; Mackrell *et al.*, 2009; Pivoto *et al.*, 2019).

No features from the external environment were included amongst the most recurrent barriers. The only barrier which might be considered to belong to this group is infrastructural deficiency, specially the lack of network connectivity.

5. Discussion and conclusions

The aim of this paper was to review the literature on farm-level MIS adoption. Given the fast development of these technologies and our attempt to consider all the possible contributions to the research topic, the study considered different types of ITs used for farm management (both computer- and mobile-based FMIS and integrated farm-level ERP systems) and extended the analysis to studies which do not only focus directly on adoption but also on software architecture design and development.

When it comes to adoption determinants, the results obtained confirm other scholars' previous findings (Pierpaoli *et al.*, 2013; Tsiropoulos *et al.*, 2017; Tummers *et al.*, 2019), specifically that technologies' technical features in fact seem to play an important role in shaping the diffusion of MIS at the farm level. On the one hand, "systemic" technical problems, such as a lack of interoperability amongst devices, a lack of data standards and elevated costs, can limit a given technology's full potential; on the other hand, another key issue that seems to determine farm-level MIS adoption and the intention to use the latter is users' individual perceptions (farmers and farm employees) of innovation attributes such as the technology's relative advantage, usability, complexity and possible customisation. Furthermore, users' characteristics together with farm features are also important adoption determinants. Age, education level and existing computer skills (users' characteristics) as well as farm size and initial technology in use (farm features) are the most recurrent factors. When limiting the focus to studies which solely address adoption, the most recurrent determinant factors seem limited to farm size, user age and education and the technology's perceived relative advantage.

5.1 Research implications

The main practical implications of this study stem from the provision of a comprehensive systematisation of factors which might determine MIS technologies adoption at the farm level. In facts, the inclusion of both conceptual and empirical types of contributions can reasonably show that adoption drivers and barriers might be due not only to users' characteristics and resources but also to technology features (Bronson, 2019). This is particularly relevant if seen as a cause behind today's unequal access to technology, i.e. the digital divide (Bronson, 2019; Carolan, 2016; van der Burg *et al.*, 2019). In this perspective, our results might be of particular interest and utility for policymakers who might find strategic to acknowledge the relevance at the same time of different types of determinants of adoption, when defining proper policies and when aiming at guaranteeing a fair and inclusive digitalisation of the agri-food sector. Moreover, technology providers and the related smart-farming technologies' industry are another type of actors who might benefit from a deeper understanding of adoption determinants. It might be easier for them to understand and successfully satisfy the requirements their customers demand.

For what concerns the theoretical implications, this study deals not only with adoption determinants but it also provides a classification of studies in terms of research focus, methods and theoretical frameworks used. Studies which focus specifically on adoption are mainly quantitative in nature (see Table 3). Looking at the evolution of these studies over time, it seems that, until 2019, scholars focussed their attention predominantly on software design and development rather than on their adoption, though adoption analyses have grown in number due to the increasing attention paid to the whole group of smart-farming technologies (Kernecker *et al.*, 2019; Knierim *et al.*, 2019; Pivoto *et al.*, 2019). When the theories used to investigate the adoption are analysed, results indicate that some scholars have used different conceptual frameworks such as DOI and TOE together to capture all the relevant factors (individual and organisational) which might drive MIS adoption and implementation (Alvarez and Nuthall, 2006; Haberli *et al.*, 2017, 2019; Lewis, 1998; Mackrell *et al.*, 2009). However, the majority of relevant factors identified in the literature so far seem to be limited to the individual action sphere. Accordingly, in the studies considered in the literature review, farmers (and, at times, both farm managers and farm employees) are generally considered the key decision-makers.

Nonetheless, in Tummers *et al.*'s (2019) recent review of FMIS literature, a wider scope of stakeholders is considered in the implementation and use of modern FMISs in the agri-food sector, as occurred in prior studies (Barmpounakis *et al.*, 2015; Kaloxylos *et al.*, 2012). Moreover, in their review on big data and smart-farming technologies, Wolfert *et al.* referred to a new possible network of stakeholders built around farms which might produce a major shift in roles and power relations amongst different players in existing agri-food chains: "We observed the changing roles of old and new software suppliers in relation to Big Data and farming and emerging landscape of data-driven initiatives with prominent role of big tech and data companies like Google and IBM" (Wolfert *et al.*, 2017, p. 75). This suggests that not only actors but also factors beyond farms' or farmers' individual circumstances might play an even more relevant role in determining MIS diffusion and adoption.

In fact, main theoretical implications deriving from the recent literature on farm-level MIS adoption indicate that the main adoption determinants identified so far in the literature reside mainly within the boundaries of the farm, in adopter units' characteristics (farmers and farms) and the technology features themselves. This study confirms that this last factor is relevant when the analysis is extended to contributions which do not focus solely on adoption.

5.2 Limitations and implications for future research

The main limitations of the study relate to the literature review approach adopted. Although the authors followed a clear structure as found in many other contributions, the review remains non-systematic; thus, it poses some limits to the replicability of the results. To reduce potential biases, the authors made any effort to clearly explicit each stage of the review process as well as any reference to how the review has been structured. Furthermore, although the authors clearly defined the technologies to be considered within the review, technological development in digital agriculture is so quick that MISs might considerably change their characteristics and as a consequence, some of their adoption determinants.

Nonetheless, the study achieved manifold and insightful results in respect to methods and theories used in recent literature. Moreover, the determinants of adoption identified so far have been classified and broadly discussed. In this respect, especially when MIS technologies are considered part of smart-farming technologies with their related ecosystems and new stakeholder networks, several interesting avenue for future research can be identified. On the one hand, an interesting research direction in studying adoption determinants would be to extend the focus to the role of additional factors beyond individual dimension (Klerkx *et al.*, 2019). In this regard, actors and organisational factors relative to the supply chain where farmers and farms carry out their activities might play an important explanatory role in unravelling the adoption and diffusion in the entire agri-food sector's digitalisation.

Another aspect which might deserve attention, as some scholars have recently pointed out, is the role played by dynamic capabilities in the digital transformation of mature industries (Warner and Wäger, 2019). Dynamic capabilities are defined as "the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments" (Teece *et al.*, 2008, p. 516). Some authors explored how these might impact business model innovation (e.g. in scouting new digital technologies or developing collaborative approaches within the innovation ecosystem) and thus enable digital transformation of the industry. Although the agricultural industry has shown traditionally poor propensity to innovate, especially in the case of small and medium farms, how the development of dynamic capabilities together with digital innovation adoption might lead to business model innovations in the agri-food sector is a topic that deserves to be further explored.

Notes

1. https://cordis.europa.eu/project/rcn/88262/reporting/en, https://www.fispace.eu/, http://smartagrifood.eu/.
2. It should be noted that, in some cases, quantitative methods (such as multivariate data analyses or econometric models) were preceded by qualitative methods such as interviews or focus groups (Haberli *et al.*, 2019).

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Corresponding author
Carlo Giua can be contacted at: carlo.giua3@unibo.it

Appendix

Table A1.
Drivers

	Ease of use, usability (D1)	Size (D2)	Education level (D3)	Possibility to customise (D4)	Relative advantage (D5)	Training (D6)	Users' skills (D7)	Initial technology equipment (D8)
Haberli *et al.* (2019)					X			X
Carli and Canavari (2014)	X							
Zheleva *et al.* (2017)								
Carrer *et al.* (2017)		X	X					
Kaloxylos *et al.* (2012)								
Haberli *et al.* (2017)		X			X			
Ibrahim *et al.* (2018)		X						
Sørensen *et al.* (2011)						X		
Verdouw *et al.* (2015)				X	X			
Rosskopf and Wagner (2003)	X			X	X	X		
Sørensen *et al.* (2010)						X		
Nikkilä *et al.* (2010)	X				X			
Mackrell *et al.* (2009)				X				
Lawson *et al.* (2011)		X	X					
Fountas *et al.* (2015a, b)	X					X		
Sørensen *et al.* (2010)								
Nurkka *et al.* (2007)							X	
Barmpounakis *et al.* (2015)								
Lewis (1998)			X					X
Kruize *et al.* (2016)				X				
Tiffin and Balcombe (2011)		X	X					
Alvarez and Nuthall (2006)		X	X					X
Husemann and Novkovic (2015)	X			X				

(continued)

	Ease of use, usability (D1)	Size (D2)	Education level (D3)	Possibility to customise (D4)	Relative advantage (D5)	Training (D6)	Users' skills (D7)	Initial technology equipment (D8)
Kuhlmann and Brodersen (2001)	X			X			X	
Engler and Toledo (2010)			X					
Fountas *et al.* (2009)	X							
Batte (2005)		X	X					
Kaloxylos *et al.* (2014)	X		X				X	
Fountas *et al.* (2015)	X	X		X				X
Fox *et al.* (2018)	X							
Pivoto *et al.* (2019)		X			X			
Sopegno *et al.* (2016)	X							
Steffe (2000)								
Allen and Wolfert (2011)		X					X	
Tsiropoulos *et al.* (2017)	X	X	X	X	X	X		
Total	12	11	9	8	7	5	4	4

Table A1.

Table A2.
Barriers

	Interoperability (O1)	Age (O2)	Costs (O3)	Complexity (O4)	Data ownership privacy and security (O5)	Data standards (O6)	Time consumption (O7)
Haberli *et al.* (2019)							
Carli and Canavari (2014)							
Zheleva *et al.* (2017)			X		X		
Carrer *et al.* (2017)							
Kaloxylos *et al.* (2012)							
Haberli *et al.* (2017)				X			
Ibrahim *et al.* (2018)							
Sørensen *et al.* (2011)							
Verdouw *et al.* (2015)			X	X			
Rosskopf and Wagner (2003)	X						
Sorensen *et al.* (2010)							
Nikkilä *et al.* (2010)	X			X		X	
Mackrell *et al.* (2009)	X						X
Lawson *et al.* (2011)							
Fountas *et al.* (2015)	X					X	
Sørensen *et al.* (2010)	X						
Nurkka *et al.* (2007)							
Barmpounakis *et al.* (2015)							
Lewis (1998)		X					
Kruize *et al.* (2016)	X					X	
Tiffin and Balcombe (2011)		X					
Alvarez and Nuthall (2006)		X	X				X
Husemann and Novkovic (2015)							
Kuhlmann and Brodersen (2001)							
Engler and Toledo (2010)		X					
Fountas *et al.* (2009)	X				X		
Batte (2005)		X					

(continued)

Table A2.

	Interoperability (O1)	Age (O2)	Costs (O3)	Complexity (O4)	Data ownership privacy and security (O5)	Data standards (O6)	Time consumption (O7)
Kaloxylos *et al.* (2014)			X		X		
Fountas *et al.* (2015)	X	X					
Fox *et al.* (2018)							
Pivoto *et al.* (2019)							X
Sopegno *et al.* (2016)	X						
Steffe (2000)			X				X
Allen and Wolfert (2011)	X	X	X		X	X	
Tsiropoulos *et al.* (2017)		X		X			
Total	10	8	6	4	4	4	4