Exploring digitalisation in agriculture through socio-technical perspectives

Chiara Cagnetti [1], Alessio Maria Braccini [1]

[1] *University of Tuscia, Department of Economics Engineering, Society and Organisation – DEIM, Viterbo VT 01000, Italy*

Abstract

The primary purpose is to explore the process of digitisation of agricultural industries from a socio-technical perspective. From the literature, we can see that digitisation can change the way agricultural industries operate and use a wide range of digital technologies. The use of these affects the entire organisation, which must have the necessary skills to adopt them. The literature analyses digital technologies in all their functional aspects and characteristics, but it less emphasizes the organisational context. For this reason, it is essential to study the digitisation process of agricultural enterprises from a socio-technical perspective. However, the research is still ongoing, so we are exploring the topic. Future research will be necessary to focus on a single technology and organize the focus on the organisational component.

Keywords

FMIS, Socio-technical perspective, Information System, Digitalisation

1. Introduction

The digital transformation uses digital technologies for improving the industry's business. The change happens both from a technical, organisational, and strategical point of view [1]—digital transformation targets all industries, including agriculture. However digital transformation, in agriculture present specific challenges but also bears significant sustainable opportunities [2].

On one side digital, transformation in the agricultural sector presents challenges similar to other industries. Part of the agricultural sector involves the collection, change, and delivery of products to the market. Under this point of view organisation of the agricultural industry use both information systems and digital technologies along with their operational and administrative processes.

Digital technologies collect data in real-time, which are processed and analysed to provide many advantages to the agricultural industry [3]. Digital technologies can influence the agriculture production process, improving the gap between farmers and suppliers. Digital technologies' main aim is to face many challenges as climate changes and the creation of added value happen in the agricultural sector [4]. Another aim is the reduction of input cost and yield improvement [5]. Managing in the real-time agriculture industry allows improving productivity, supply chain efficiency, safety, and use of resources [3].

On the other side, the agricultural sector is highly diversified and contains organisations that work in different conditions. For part of them, the production and transformation process happens in nature, in farms of various sizes, and depends on events of the natural environment. Digital technologies need to be deployed in such contexts, which poses new challenges for IoT solutions.

Furthermore, digital transformation in the agricultural industry is preliminary since several organisations are at a pre-digital phase, small size, not integrated into value chains, and lack staff with good digital literacy [3].

7th International Workshop on Socio-Technical Perspective in IS development (STPIS 2021) 11-12 October 2021, Trento, Italy
EMAIL: chiara.cagnetti@unitus.it; abraccini@unitus.it

There are several studies on digital transformation in the agricultural industry [2]. Most of the studies focus on the operational benefits of integrating single pieces of technology. In this exploratory paper, we aim at exploring the literature on digital transformation from a socio-technical perspective to draw avenues for future research in the industry. The paper is driven by the following research question: *What is the state of the art of literature on digital transformation in the agricultural industry from a socio-technical point of view?* We answer to research question through a literature review.

In this regard, the paper is structured as follows. In Section 2, we present a theoretical framework from a socio-technical perspective. In section 3, we show the material and method used in the literature review. In section 4, we show the results of the literature review. In Section 5, we discuss the preliminary results of the literature review, answering the research question. Finally, in section 6, we conclude by identifying how to continue for future research.

2. Theoretical framework

The socio-technical perspective arose after World War II, along with the studies undertaken in the British mining industry by the Tavistock Institute. A new way of thinking was born, and programmatic moves developed to resolve the gap between organisational and technical approaches to problem-solving. A unique way of studying the relationship between technological and social components was born [6].

The socio-technical perspective considers a working system composed of two intertwined elements: the social and the technical. The technical component evaluates the business processes and the technologies used in the industry to perform the operations. The technical component transforms inputs into outputs to improve the performance of the work system [7]. The technical component is a "*human-created tool whose raison d'être is to be used to solve a problem, achieve a goal or serve a purpose that is human-defined, human perceived or human felt*" [8].

On the other hand, the social component comprises individuals, knowledge, skills, attitudes, values, and needs in the industry and the external environment [7]. The social component is a "*relationships or interactions between or among individuals (or collectives) through which an individual (or collective) attempts to solve one of his or her (or their) problems, achieve one of his or her (or their goals or serve on of his or her (or their) purposes relationships"* [8].

The two components interact with each other, and both assume importance in generating satisfactory results. The two components must work together to realize tasks to produce a physical product and social/psychological effects. We consider the social and technical components together to produce positive results, and this concept is called joint optimization. The technical feature designed in advance of the social element is contrasted by this method [9]. The socio-technical perspective does not privilege the technological or social features but sees results emerging from the interaction between the two components.

3. Research design

We conducted the literature review following specific theories [25, 26], identifying ways, techniques, and advice to follow to perform a good review. We identified information about the socio-technical perspective in agriculture industries through the literature review, extracting the information required to conduct our analysis. The literature review is a part of the systematic, which allows us to identify, evaluate, and synthesize the research. We identified a research question, which we could answer by collecting, extracting, and aggregating information. We conducted an iterative search; in fact, we initially searched the literature for Farm Management Information system (FMIS) and Decision Support System (DSS) and, as we drove the review, learned about new topics and concepts that led to extending the initial search by accepting new work.

We use Scopus and Web of Science (WoS) to search for materials. We chose these two online databases because they are the most relevant in our field of study and allow us to search through a query. We use a search through a query to properly link topics together but, more importantly, to achieve an exhaustive search. We formulate a research query to study the concept of FMIS and DSS in the agricultural sector, intending to analyse these concepts according to a socio-technical perspective. Show the query in Table 1 below.

"Title, keywords, Abstract" is the search criteria. We limited the results to "Papers," and we chose only "Journal." Then we identify the topic areas, like Scopus and WoS. We use in Scopus: "agriculture and biological sciences," "social sciences," and "business, management, and account.". We use these research areas in WoS: "Agriculture," "Business Economics," and "Social Sciences topics."

We select only papers in English and perform the search in January and February 2021. We read the obtained papers and tried to select only the most relevant to the research, excluding those that would not add value to the study. We read the abstracts of all papers found and chosen only the most pertinent, excluding any duplicates found. Next, we read the selected papers thoroughly and removed those that would not benefit the search. The reports we obtained were able to satisfy our search. While reading the papers, we conducted a back-and-forth search, through which we identified essential themes to our research that were initial search found. To write the paper, we consider papers from the last ten years, but to get a clearer view of the topics, we read all papers since 2000. We chose to select only this time frame because the concept of Smart Farming was born in the last few years, and therefore in the past years, we would not have found helpful information about this concept.

Table 1
Literature Review

Phases	Description of actions	N° of Papers
1	((agriculture farm) AND ("decision support system" OR "agricultural decision support system" OR "business intelligence") AND ("farm* management" OR "corporate performance measurement" OR "performance management" OR "performance measurement"))	34 Scopus 11 WoS
2	Duplicates papers	6
3	The final number of papers from the literature search	39
4	Abstract read selection	18
5	Full-texted selection	14
6	Relevant paper cited	19
Total	Total number of Papers used in the literature review	33

4. Preliminary Results

The literature review identified various technologies that farmers use in agricultural industries and contribute to agricultural sectors' digitalization. These include information systems (IS), which farmers use in the agricultural industry. Information systems are technologies implemented in farms that have started a digitalisation process, but their use in the agricultural industry is still limited. The information systems used in agriculture and identified by the literature review are farm manager Information Systems (FMIS). In addition to these IS, we also identified another technology used in agriculture: decision support system (DSS). Below we identify the characteristics of these concepts, and we show what they are specific features and their use.

4.1. The FMIS and its characteristics

The FMIS is an IS that collects and processes data to perform farm operations and keep track of data and relationships with third parties. The FMIS is defined as "*a planned system for the collecting, processing, storing, and disseminating data in the form of information needed to carry out the operations functions of the farm*." The FMIS performs specific operations such as strategic, tactical, and operational planning, implementation and documentation of data and evaluations, and work optimization [10]. For these, the objectives of FMIS are to provide and collect information from farmers, offer intelligent services, reduce production costs, respect agricultural standards, and maintain a high quality and products safety [10, 11]. The use of FMIS has an impact on the whole organisation. Indeed, the effects of FMIS are improving decision making, easy to use software through interaction between end-user and developer, and finally, producing appropriate documentation to reduce time management [11].

Like all the information systems (IS), FMIS has limitations such as lack of farmers' expertise, problems to transfer data, lack of environmental events to make comparisons, lack of trust from farmers to use this technology [10, 12].

From literature, we can see that more stakeholder is interesting to improve FMIS. Each stakeholder plays a different role. For example, one of the primary stakeholders is the farmer, responsible for the agricultural industry and the end-user of software. The developer creates software and FMIS, and the agricultural consultant is the one who helps farmers make decisions, and the FMIS assisting him. There are other stakeholders, for example, accountants, who use FMIS to verify information in accounting. The FMIS contains information for the agricultural industry and stakeholders. For example, financial management, traceability, accountability, data processing, and resource management [13]. FMIS is not unique. Indeed, it changes according to the type of agricultural industry. However, there are eleven generics functions that all FMIS must-have. These functions are field operations management, best practices, finance, inventory, traceability, reporting, site-specific, sales, machinery management, human resource management, and finally, quality assurance [11].

The FMIS is designed with various conceptual models, using specific software development techniques such as Unified Modelling Language (UML). This language is an industry-standard to make object-oriented analysis and realization of information systems. The UML describes the relationship among various software components of the agricultural industry. There are other methodologies, such as Relationship diagrams and data flow. There is no single standard architecture for developing an FMIS. Indeed, there are several. We find that FMIS, with client-server architecture and others, is standalone [13, 14].

This architecture can be formally or informally. When the design is informal, the plan does not follow formal modeling techniques but uses line and box models. Formal structure uses defined standards ISO/ISEC and Standard 42010 (ISO/IEC/IEEE 42010 2011) [13, 14]. FMIS can be an application or standalone application. A platform is software with a plug-in architecture that helps users or the agricultural industry extend functions of FMIS. The Platform is a program for pc to perform an activity. There are three types of platforms: Web FMIS, Mobile FMIS, and Desktop FMIS. The Platform is usually computer-based [11].

Ultimately, however, FMIS based on the Internet of Things (IoT) is becoming essential. These technologies are integrated with FMIS to create systems with different functional requirements, for example, type of crop, sensors, communication protocols, and data processing capability. The architecture is so complicated to achieve but can generate good results. FMIS based on IoT supports objectives of smart farming, and it can use this technology jointly to create added value [15].

Using these technologies involves changes depending on the type of industry and its size from the organisational side. Large agricultural industries use these digital technologies, which have a more significant number of workers. The application of technologies also involves a change in the industry's culture and mentality of the industry. Organisations play a crucial role in the use of digital technologies and must be proactive. Organisations' attitudes influence the usage of digital technologies; in fact, workers with positive attitudes can gain advantages over other industries.

4.2. DSS in agriculture

A DSS is a platform to support decision-making by facilitating the creation of situations from farm data, which help farmers make decisions [16].

DSS in agriculture is a human-computer system that can use the collected data to provide farmers with a list of recommendations that they can implement in their decision-making process. DSS does not replace farmers' work but helps them make better decisions even though farmers often make decisions independently [16]. According to a socio-technical perspective, DSS are digital technologies integrated into the decision-making process of farmers. Agricultural industries use these digital technologies to achieve their objectives and follow their strategies in the best possible way.

The main functions of DSS are [17]:

1) Collecting, organizing, and integrating different types of information needed to produce a crop

2) To Analyse and interpret the information

3) Using the analyses to recommend the most appropriate action and choices of action.

Today's decision-making process uses data sources that create opportunities for information and drive a change from intuitive to data-driven, real-time decision-making. This change involves new ways of working. DSSs usually result in a database or data model, a logic-based or logical model, and a user interface. The logical model is a mathematical simulation model that describes how entities or a group of entities react under certain circumstances, ground rules, or a combination of the two [18].

There are various types of DSS in agriculture, each with specific tasks. There are DSSs used for field management, others for irrigation management, and still others for vineyard management. Each of these has different characteristics and usefulness.

Organisations play a crucial role in the use of digital technologies and need to be proactive. The use of digital technologies must be an increase in jobs in the organisation, but rather as elements that can help workers. Digital technologies require specific knowledge and a reorganisation of roles according to skills possessed. The use of DSS helps farmers make decisions and requires coordination and control throughout the organisation.

5. Discussion

This paper is a "Work in progress paper" and represents a research question from a Ph.D. project. We conduct a literature review in which the agricultural industry's digital transformation, digital technologies, and digitalisation are the framework. We explore the concept of agricultural industries, FMIS, and DSS from a socio-technical perspective

We research in collaboration with CREA, an Italian governmental research organisation dedicated to agri-food supply chains. CREA operated as a legal entity and supervised of Ministry of Agricultural, Food, Forestry, and Tourism Policies (Mipaaft). Their activities regard agriculture, crops, livestock, forestry, food science- and socio-economics. CREA tries to respect the aim of sustainability through circular economy standards and innovations.

The research focuses on DSS and FMIS, the creation of DSS to support decisions derived from data collected by agricultural industries. The analog country is Italy, which is part of the European Union. Italy is a developed country but adopts few digital technologies in agricultural industries, even though agriculture is essential. In the primary phase, we use only a tiny part of the literature review to show how the socio-technical perspective can influence the agricultural industry. The literature review indicates that there are many studies about the application of digital technology and their feedback in the organisation but on t. Still, there are few studies on how the organisation changes its functioning with digital technologies.

So far, the research is at a very early stage, and we have no example concerning digital technologies in agricultural industries. We only consider the literature review, and we cannot give a practical example. We want to identify specific agricultural sectors for the following research to understand and analyse how agricultural industries use digital technologies and impact the organisation. For now, we recognize the following from the literature review.

The digitization process in agricultural industries is still ongoing. It transforms the way industries work, moving from standardized to digital methods using digital technologies that improve industry profitability and productivity. We used a part of the conducted literature review to show the state-of-the-art digitalisation in agricultural industries from a socio-technical perspective to answer our research question. The literature review offers a low adoption of digital technologies in agricultural sectors, and indeed, the digitization process is still ongoing and has not taken place completely. The literature review identified two digital technologies that contribute to the digitalisation process in agricultural industries, namely FMIS e DSS. These digital technologies are essential because they help farmers to make decisions based on data and not only on their knowledge and intentions. Agricultural industries do not use them due to the lack of skills. From a socio-technical perspective, it is a necessary collaboration between technical and organisational to solve these problems. These components are interconnected and influence the digitalisation process of agricultural industries. The technical feature is the FMIS; during the administrative element, the actors are the farmer. The FMIS collects and processes data to perform farming operations and keep track of the data while people get the results and use them to make the best decisions. To develop digital technology, necessary a collaborative process between the farmer and the developer must be successful.

One of the limitations of using FMIS is the difficulty and complexity, so develop a simple technology [10, 12, 13, 23, 24].

DSS is also digital technology that contributes to the digitization process of the agricultural industry. DSS helps to make better decisions for the farmer without replacing his work. From the literature, we notice that digital technologies focus their interest from a technical point of view without understanding their role in the organisation. Many organisations adopt digital technologies when they are supported by other organisations that can explain their benefits. Organisations that decide to use digital technologies can improve their management capacity, but more importantly, many believe that technologies improve business results. Organisations need to support the use of technologies to improve their digital infrastructure, but above all, they need to use digital technologies that are usable by all users [4]. According to a socio-technical perspective, digital technologies are the combination of technologies that can influence the organisation and manage its business processes. Organisations need to change their attitudes and be willing to apply digital technologies. Perspectives should not be individual but collaborative between people working in industries and between people and technologies, as digital technology should be necessary for their activities. Organisations adopt technologies when they are willing to overcome the limitations of lack of skills, thus overcoming their technological backwardness socio-technical [19]. In addition to these reasons, the organisation often has a pessimistic attitude about its adoption because of data issues, environmental constraints, and a lack of value.

Digital technologies in agricultural industries aim to capture infinite amounts of data to be used to make decisions. The absence of legislation contributes to the low adoption of these digital technologies, which are not adopted because there is no control over the data. The development of digital technologies by developers is not always easy. Often digital technologies are combinatorial, and agricultural industries do not use these for considered too demanding. Creating a unique software developed by a developer is a wrong solution. Users prefer to use customized software, consisting of standardized components provided by various developers, who collaborate and compete through the development of a platform. Creating such software requires a strong organisation willing to collaborate with stakeholders to create programs that depend on the organisation's expertise [3, 5, 20].

The use of digital technologies requires changes within the organisation, as digital technologies require specific skills and a working environment conducive to change. The organisation must be interested in changing its activities, integrated with digital technologies to generate positive feedback. The organisation will only use digital technologies if they can cause significant benefits for the organisation. The application of digital technologies, which modify processes and make them digital, requires an organisational redesign, which depends on the objectives set and the new organisational structure. The use of technology also entails changes at the level of employees, whom digital technologies can often replace. When this happens, companies must review their hierarchy but find new solutions for their workers. Organisations also need to incentivize workers, in this case, farmers, to boost and increase their skills.

They analyse the results obtained, and we see that the organisation's low adoption of digital technologies could limit technology's improvement. Agricultural industries that do not adopt digital technologies cannot even develop and improve. If digital technologies fail to build, it will not be possible to implement a digitalisation process of agricultural industries. The organisation needs staff with specific digital skills, and in their absence, it can resort to specific courses able to increase the digital level of the organisation. If employees improve their skills, they will apply digital technologies, and organisations could achieve benefits and high performance. Expanding a company's performance enables it to achieve important goals. Of course, agricultural enterprises that decide to implement digital technologies must have strategies to follow and plans and objectives to reach, considering any issues.

The use of digital technologies such as DSS and FMIS for the digitisation process requires the co-invocation of both technical and organisational aspects. Considering these two elements in the digitisation process of agricultural industries will allow solving the problems that still exist related to the poor implementation of these digital technologies.

Using digital technologies such as DSS and FMIS for the digitization process requires the co-invocation of technical and organisational aspects. Considering these two elements in the digitization process of agricultural industries will allow solving the problems that still exist related to the poor implementation of these digital technologies.

6. Conclusion

The research shows that agricultural industries are in a transition phase towards the digitalisation process. Digital technologies are studied individually and need to be integrated with the organisational context to gather helpful information to apply the digitalisation process. As already mentioned, the research is still ongoing. It is necessary to analyse the digitalisation process from a socio-technical perspective, integrating the theoretical component with the organisational piece. This perspective improves the digitalisation process that has advantages and limitations. The organisation must integrate these digital technologies with their operations and activities, be aware of them and have the appropriate knowledge to use them. To study the digitalisation process of agricultural industries in even greater detail, it is essential to orient studies towards a socio-technical perspective. The latter, in the present research, needs to be more investigated. Until now, we give importance to the role of technologies and do not consider the organisational part.

7. References

1. Parra-López, C., Reina-Usuga, L., Carmona-Torres, C., Sayadi, S., Klerkx, L.: Digital transformation of the agri-food system: Quantifying the conditioning factors to inform policy planning in the olive sector. Land use policy. 108, (2021). https://doi.org/10.1016/j.landusepol.2021.105537.
2. Klerkx, L., Rose, D.: Dealing with the game-changing technologies of Agriculture 4.0: How do we manage diversity and responsibility in food system transition pathways? Glob. Food Sec. 24, (2020). https://doi.org/10.1016/j.gfs.2019.100347.
3. Liu, Y., Ma, X., Shu, L., Hancke, G.P., Abu-Mahfouz, A.M.: From Industry 4.0 to Agriculture 4.0: Current Status, Enabling Technologies, and Research Challenges. IEEE Trans. Ind. Informatics. 17, 4322–4334 (2021). https://doi.org/10.1109/TII.2020.3003910.
4. Hashem, N.M., Hassanein, E.M., Hocquette, J.-F., Gonzalez-Bulnes, A., Ahmed, F.A., Attia, Y.A., Asiry, K.A.: Agro-Livestock Farming System Sustainability during the COVID-19 Era: A Cross-Sectional Study on the Role of Information and Communication Technologies. Sustainability. 13, 6521 (2021). https://doi.org/10.3390/su13126521.
5. Fielke, S.J., Garrard, R., Jakku, E., Fleming, A., Wiseman, L., Taylor, B.M.: Conceptualising the DAIS: Implications of the 'Digitalisation of Agricultural Innovation Systems' on technology and policy at multiple levels. NJAS - Wageningen J. Life Sci. 90–91, (2019). https://doi.org/10.1016/j.njas.2019.04.002.
6. Sarker, S., Chatterjee, S., Xiao, X., Elbanna, A.: The sociotechnical axis of cohesion for the IS discipline: Its historical legacy and its continued relevance. MIS Q. Manag. Inf. Syst. 43, 695–719 (2019). https://doi.org/10.25300/MISQ/2019/13747.
7. Bostrom, R., Gupta, S., Thomas, D.: A meta-theory for understanding information systems within sociotechnical systems. J. Manag. Inf. Syst. 26, 17–48 (2009). https://doi.org/10.2753/MIS0742-1222260102.
8. Lee, A.S., Thomas, M., Baskerville, R.L.: Going back to basics in design science: From the information technology artifact to the information systems artifact. Inf. Syst. J. 25, 5–21 (2015). https://doi.org/10.1111/isj.12054.
9. Appelbaum, S.H.: Socio-technical systems theory: an intervention strategy for organisational development, (1997). https://doi.org/10.1108/00251749710173823.
10. Kaloxylos, A., Eigenmann, R., Teye, F., Politopoulou, Z., Wolfert, S., Shrank, C., Dillinger, M., Lampropoulou, I., Antoniou, E., Pesonen, L., Nicole, H., Thomas, F., Alonistioti, N.,

Kormentzas, G.: Farm management systems and the Future Internet era. Comput. Electron. Agric. 89, 130–144 (2012). https://doi.org/10.1016/j.compag.2012.09.002.
11. Fountas, S., Carli, G., Sørensen, C.G., Tsiropoulos, Z., Cavalaris, C., Vatsanidou, A., Liakos, B., Canavari, M., Wiebensohn, J., Tisserye, B.: Farm management information systems: Current situation and future perspectives. Comput. Electron. Agric. 115, 40–50 (2015). https://doi.org/10.1016/j.compag.2015.05.011.
12. Kaloxylos, A., Groumas, A., Sarris, V., Katsikas, L., Magdalinos, P., Antoniou, E., Politopoulou, Z., Wolfert, S., Brewster, C., Eigenmann, R., Maestre Terol, C.: A cloud-based farm management system: Architecture and implementation. Comput. Electron. Agric. 100, 168–179 (2014). https://doi.org/10.1016/j.compag.2013.11.014.
13. Tummers, J., Kassahun, A., Tekinerdogan, B.: Reference architecture design for farm management information systems: a multi-case study approach. Precis. Agric. 22, 22–50 (2021). https://doi.org/10.1007/s11119-020-09728-0.
14. Tummers, J., Kassahun, A., Tekinerdogan, B.: Obstacles and features of Farm Management Information Systems: A systematic literature review, (2019). https://doi.org/10.1016/j.compag.2018.12.044.
15. Köksal, Tekinerdogan, B.: Architecture design approach for IoT-based farm management information systems. Precis. Agric. 20, 926–958 (2019). https://doi.org/10.1007/s11119-018-09624-8.
16. Zhai, Z., Martínez, J.F., Beltran, V., Martínez, N.L.: Decision support systems for agriculture 4.0: Survey and challenges, (2020). https://doi.org/10.1016/j.compag.2020.105256.
17. Lindblom, J., Lundström, C., Ljung, M., Jonsson, A.: Promoting sustainable intensification in precision agriculture: review of decision support systems development and strategies. Precis. Agric. 18, 309–331 (2017). https://doi.org/10.1007/s11119-016-9491-4.
18. Parker, C., Sinclair, M.: User-centred design does make a difference. The case of decision support systems in crop production. Behav. Inf. Technol. 20, 449–460 (2001). https://doi.org/10.1080/01449290110089570.
19. Ulezko, A., Reimer, V., Ulezko, O.: Theoretical and methodological aspects of digitalisation in agriculture. IOP Conf. Ser. Earth Environ. Sci. 274, (2019). https://doi.org/10.1088/1755-1315/274/1/012062.
20. Kruize, J.W., Wolfert, J., Scholten, H., Verdouw, C.N., Kassahun, A., Beulens, A.J.M.: A reference architecture for Farm Software Ecosystems. Comput. Electron. Agric. 125, 12–28 (2016). https://doi.org/10.1016/j.compag.2016.04.011.