

Exploring Barriers and Needs in the Adoption of Digital Farming Technologies: Insights from Italian Stakeholders in the Food Supply Chain

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Abstract

Digital agriculture technologies represent a solution for improving productivity levels and environmental sustainability by collecting, integrating and analysing data with great potential from different sources. The potential disruptive impact of digital agriculture makes it particularly important to understand the mechanisms of adoption and diffusion of digital farming technologies. Indeed, the existing literature clearly shows that multiple factors involved in the decision-making process are responsible for farmers' technology adoption rate. However, their knowledge is still incomplete. Individual, technological, social, and economic factors influencing technology adoption at both farm and system levels can depict the overall decision-making process. The approach of this paper is to explore farmers' adoption process from the Italian stakeholders' perceptions of needs and demands for digital technologies. The main objective is to analyze the barriers to adoption and drivers to the diffusion of system innovations by using a combined qualitative research method with focus groups and semi-structured interviews.

Results from content analysis point out that a crucial precondition for embracing digital transformation is the interaction between different stakeholders, promoting cooperation as a key strategy. Collaborative efforts through technical support and training activities have the potential to moderate business risks, foster individual competitiveness and strengthen overall investment capacity in the agricultural sector.

Keywords: digital farming technologies; stakeholders; food supply chain; technology adoption.

Introduction

Global agriculture needs to increase overall productivity to meet the demand for food, feed and fibers in the coming years while also targeting environmental challenges (Finger et al., 2019; Navarro et al., 2020).

In this regard, digital technologies are of paramount importance in improving productivity levels and environmental sustainability by generating large amounts of information with great potential that the whole sector needs to accurately and effectively manage (European Commission, 2020; Lytos et al., 2020; Medici et al., 2021). Digital agriculture can be seen as an extension of precision agriculture (Sponchioni et al., 2019) as it does not refer to a specific application. Still, the collection, integration and analysis of data from different sources is considered. Agriculture 4.0 comprises technologies combining sensors, information systems, enhanced machinery, and informed management to optimise production by accounting for variabilities and uncertainties within agricultural systems (Mammarella et al., 2022). The rise of these technologies and the potential disruptive impact of digital agriculture make it particularly important to understand the mechanisms of adoption and diffusion of digital farming technologies (Shang et al., 2021).

The existing literature clearly shows that multiple factors involved in the decision-making process are responsible for the technology adoption rate by farmers (Osrof et al., 2023).

According to recent studies, in Italy, agricultural technology adoption is still at an early stage (Politecnico di Milano, 2023). Indeed, several points of misalignment between supply and demand have been found in the Italian smart farming market, and the services offered do not fully meet the real needs of farms. However, the knowledge of factors affecting farmers' decision-making is still incomplete.

Although the literature has studied the mechanisms of innovation diffusion for several years, there seems to be no convergence in the theories and models that could explain the phenomenon. De Oca Munguia and Llewellyn (2020) find a lack of clarity about analytical methods and the choice of explanatory variables that should be used to model adoption.

In addition, Shang et al. (2021) state that the mechanisms of adoption and diffusion of digital farming technologies must be understood at both farm and system levels, and they pay attention on system interactions in combination with individual characteristics in determining technology diffusion. Several examples of categorizing determinants of digital agricultural technologies have been provided in the literature (Kakkavou et al., 2024; Osrof et al., 2023; Shang et al., 2021; Troiano et al., 2023). However, not many studies focused on farmers' knowledge of digital solutions and their level of adoption (Maffezzoli et al., 2022).

In general, the ability of farmers to adopt digital solutions and the further integration of the collected data in their current working setting is influenced by different components, such as farm and operators' characteristics, interactions with peers and institutions, technology attributes and attitudinal aspects (Osrof et al., 2023; Shang et al., 2021).

Based on evidence from the literature, categories of individual, technological, social, and economic factors that influence technology adoption can depict the overall decision-making process (Dissanayake et al., 2022).

In particular, some authors highlighted the importance of considering stakeholder perceptions and engaging them in developing and scaling up a resilient innovation framework to effectively deploy technologies on farms (Reimer et al., 2023; Vecchio et al., 2022).

This paper describes an explorative study to analyze the stakeholders' needs and demands for digital technologies along the Italian food supply chain and the barriers that hinder the diffusion of system innovations.

For this purpose, this study wants to explore stakeholders' perceptions of adoption barriers and diffusion drivers and assess stakeholders' demand for the full tracking of field farming activities.

Materials and methods

The investigation was based on two alternative qualitative research methods, focus groups and interviews, that have been previously used to investigate stakeholders' decision-making process in the agri-food sector (Galabuzi et al., 2021; Marcu et al., 2015; Osei et al., 2021).

Focus Groups (FG) were planned to discuss stakeholders' demands and barriers in relation to the use of tools for tracing farming activities at the field level. In-depth interviews were designed to deepen the understanding of those demands and barriers from the perspective of key actors.

An FG is a discussion conducted by a moderator in a non-structured and natural manner with a small group of participants (Malhotra et al., 2013) that is aimed to generate creative discussion by promoting interactions within the group and capturing opinions, motivations, decisions, and priorities about a particular area of interest.

In-depth interviews are also used as a combined research method, with FGs providing a space for extended conversations that allow for more insightful results (Monteiro Moretti et al., 2023; Osei et al., 2021). We used semi-structured interviews as the most common type, based on a topic guide driven by the focus group outcomes.

Two FGs were conducted with 14 participants in total, from farmers' associations to farm entrepreneurs and machine and service providers. One was held on February 2023 in Bologna (Emilia-Romagna Region, Italy) with 6 participants, and a second was held on September 2023 in Catania (Sicily Region, Italy) with 8 participants.

Along with the FG meetings, 14 semi-structured interviews have been administered among a wider range of stakeholders from different tiers of the food supply chain to focus on their needs regarding digital technologies' adoption and to discern the heterogeneity of the adoption's barriers.

The entire selection of participants was based on a purposive sampling approach, which is generally considered the most useful mode for interview-based research since the number of interviews to be conducted is too small to aim to be statistically representative (Knott et al., 2022).

The participants were selected from the Italian food supply chain based on the following inclusion criteria: the interviewees play a role within the supply chain and are interested in the innovation system under investigation. The topic for the discussion was aimed at understanding i) the data needs of each actor along the supply chain, ii) the major barriers to digital technology adoption and iii) the major benefits of digital technology adoption.

The semi-structured interviews concerned general perceptions of digital farming technologies, barriers and drivers of technologies' adoption and the needs of digital farming technologies in managing field activities, resulting in a total of 7 open-ended questions.

In FG and interviews, stakeholders were informed about the study's objectives.

The data collection sessions were performed from February to October 2023. The FGs lasted around 1 hour and 30 minutes, and the interviews lasted around 1 hour each.

To obtain a subjective interpretation validated within the research group, the transcriptions of the interview texts and FGs were analysed through latent content analysis, a research method that, through a systematic and objective process, produces valuable inferences from verbal, visual and written data, aiming at describing and quantifying a specific phenomenon (Downe-Wamboldt, 1992).

Results

Data analysis allows to identify three major themes: the data requirements to manage the farming activities better, the characteristics of the innovation adoption process, and the benefits related to the technologies' adoption, each of them composed of different units of sense that may represent opportunities or challenges regarding the adoption and diffusion of AG 4.0.

Data requirements

This theme encloses four different units of sense that participants have reported: data availability, data requirements, data management and data security and property.

Data availability and requirements refer to the current availability and usefulness of data for farm management from whatever source they originate. Most of the participants stated that even though farm data availability is commensurate with their functional needs, which have no requirements for additional data, the potential is not fully exploited due to their inability to use technologies and lack of usefulness awareness.

Data management encompasses anything related exclusively to farmer data use and certainly, the element to which stakeholders placed the most importance was the complexity in managing and processing data rather than collecting. In most cases, data integration from different sources such as machine sensors, remote sensing, field observations, and data interoperability between different protocols were the attributes of complexity more emphasised.

Finally, **data security and ownership** were investigated with respect to the perceived risk of manipulations and attention to digital rights and intellectual property. Overall, participants perceived a generally low risk of misappropriating sensitive data in the collection and management process, evaluating it more as an opportunity to improve farm operability through sharing data rather than as a threat.

Innovation adoption process

Overall, the adoption process was the most significant issue, receiving great attention from all the participants. It refers to the determinants of the adoption and diffusion of digital farming technologies and includes two further units of sense: barriers and drivers to adoption. Participants focused more on the **Barriers to adoption** rather than the drivers for diffusion, identifying many factors that may hinder the adoption of a technology and that prevent the purchase and use of specific equipment.

The main barriers affecting technology adoption that emerged were: the lack of attitude and trust toward innovations; cultural barriers; the lack of awareness of technology benefits and utility; the low investment capacity especially for smallholders compared to the high technology costs; the lack of technical support in collecting and interpreting data; the lack of awareness of the importance of the technical support; the lack of technical expertise at different levels of the supply chain; farm structures in terms of bio-physical conditions, specialisation and crops profitability.

Concerning the **drivers of diffusion**, it strongly emerged that the trigger for the use of digital technologies in agriculture is the ability to improve the economic performance of farms by reducing operational costs. However, participants highlighted the importance of improving environmental performances, particularly for marginal areas, and in some cases, the pivotal role of the interactions among actors emerged in increasing competitiveness through aggregation, spreading information and building trust in the digital farming system.

Adoption benefits

This theme includes the benefits according to the triple bottom line (TBL; that is, people, planet, and profit) principles (Norman and MacDonald, 2004), and benefits from any aspect that contributes to improving relationships with stakeholders in the supply chain. Among the adoption benefits reported by participants, the **economic advantages** were considered the most important, even though a lack of strategic economic analysis was found. Conversely, the **social advantages** related to safety and working conditions appeared poorly understood; they were reported in a few cases. The environmental advantages have been given sufficient consideration, especially by linking them to economic benefits. Finally, the capacity to implement **supply chain relations** was well-valued.

Discussion

Our research contributes to the study of factors involved in the farmer's decision-making process in adopting digital farming technologies, exploring the perceptions of Italian stakeholders along the food supply chain to provide a systemic overview of the process and capture interactions within the system.

Our findings show several barriers and drivers for the adoption and diffusion of digital technologies in crop production and provide useful insights into farmer's needs and solutions to boost farm digital transition.

Italian farmers from our sample cannot fully exploit their current technology endowment and integrate it into their actual work setting because they are unaware of technology's usefulness and benefits, requiring more technical support and training activities.

Stakeholders' evidence regarding factors affecting farm technology adoption is consistent with the extended field literature (Osrof et al., 2023; Shang et al., 2021; Troiano et al., 2023). In fact, they identify both structural and individual factors affecting the decision-making process.

Respondents align with the recent literature (Kakkavou et al., 2024; Vecchio et al., 2022, 2020) in underlining the leading role of behavioral factors and individual perception, affecting the propensity to innovate.

The majority of stakeholders interviewed highlighted the role of economic and environmental benefits in adopting digital farming technologies (Osrof et al., 2023; Shang et al., 2021; Troiano et al., 2023) and only in few cases evaluated the role of the interactions among actors as pivotal.

This finding suggests delving into individual factors and figuring out how to overcome them through system interactions. Indeed, literature focused on the influence of social relations on adoption, suggesting it as a strategy to overcome hurdles and improve innovations (Busse et al., 2014; Monteiro Moretti et al., 2023).

Even more interesting, participants in the study point out the lack of expertise in the supply chain and their necessity to access more effective technical support and training activities to develop awareness of technology's usefulness and benefits. This concept relates to the systemic approach reported in recent literature (Masi et al., 2022; Monteiro Moretti et al., 2023), which states that interactions among actors (especially meso-actors) can spread awareness, information and knowledge within the innovation system by contributing to overcome barriers.

Conclusion

Perceiving digital transformation from a perspective of interaction between different stakeholders, is a crucial precondition for embracing this innovative process.

Promoting cooperation emerges as a key strategy in light of the potential obstacles and complexities involved in this transition. Collaborative efforts have the potential to moderate business risks, fostering individual competitiveness and strengthening overall investment capacity in the agricultural sector. By addressing these identified challenges through strategic policies and collaborative training programs, the farming industry could effectively address digital transformation, ensuring sustainable growth and resilience in the face of evolving technological demands.

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