**Chapter N (please do not write anything in this line. Editors will annotate the chapter number)**

**Key factors of Digital agriculture on competitiveness, sustainability, and safety areas**

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**Abstract.** Digital transformation (DT) is progressively changing the paradigm of agricultural enterprises. The adoption of new digital technologies such as the Internet of things (IoT), machine learning, cloud, artificial intelligence, and big data have the aim, at the first moment, to increase productivity and product quality and reduce environmental impacts (Shepherd et al., 2020). Several studies investigate the characteristics and applications of digital technologies in the agricultural sector (Cannas, 2021; Carmela Annosi et al., 2020; Michels et al., 2020). However, there are still few works that link economic, safety, and environmental impacts to these drivers of development. Therefore, through a critical review of the literature, this paper aims to identify factors acting in competitiveness, sustainability, and safety. The articles identified from the literature were selected through a review process using the Scopus database. The search through the keywords "Digital agriculture", "High tech farming", "Sustainability", "Competitiveness", "Economic", "Traceability and Safety" returned 128 articles. The results made it possible to identify key factors and describe their influence on the reference areas.

**Keywords.** Digital agriculture; High tech farming***;*** Sustainability; Safety; Competitiveness.

**1.1 Introduction**

The Digital transformation (DT) process is progressively contributing to increasing productivity and improving value creation opportunities along the production chains. In recent years, the DT has begun to develop also in agricultural enterprises, aiming to connect the farmers and countryside with the digital economy, modernizing businesses and their sustainable future (Rijswijk et al., 2021). Industries improve traditional business and operation, adding more options using innovative technologies (Ebert & Duarte, 2018).

This transformation has contributed to improving techniques of production and productivity (Dinelli et al., 2022), and generating benefits and risks in agricultural enterprises (Xie et al., 2021). It modifies how farmers work, creating social, economic, and environmental impacts (Lioutas et al., 2021). Adopting progressive digital technologies such as big data, robotics, the Internet of things, or sensors in the production system is trying to improve and make production and livestock more efficient (Birner et al., 2021). Many studies investigate digital technologies' DT and relative application in agricultural enterprises (Amentae & Gebresenbet, 2021). Still, no studies in the literature systematize the impact of digital agriculture on sustainability, security, and competitiveness. This paper aims to identify key factors acting in digital agriculture, such as competitiveness, sustainability, and safety.

The contribution is structured as follows. Section 2 defines the methodology used to conduct the literature review, and in section 3, we present the results and discussion. Finally, section 4 includes the conclusions and implications for further research.

* 1. **Methodology**

A literature review was conducted using a specific methodology (Watson, 2002) to answer the research question. The database used to research literature is the SCOPUS database, including scientific publications until March 2022. The query used for research is (ALL ("digital agriculture" OR "high tech farming") AND ALL ("sustainability") AND ALL ("competitiveness" OR "economic") AND ALL ("traceability" OR "safety")). The query returned 128 articles, extracted, and organized in an Excel database. The authors selected the papers. A first analysis of the title and abstract allowed the selection of 49 preliminary articles. An in-depth analysis of the full-text authors identifies 37 total papers used for this research. The literature review enables us to create a conceptual matrix to summarize the articles identified by the review process. The authors classify items according to the three Areas (Competitiveness, Sustainability, and Safety) proposed by (Poponi et al., 2022).

**Table 1. Description of the literature search protocol**

|  |  |  |
| --- | --- | --- |
| Stage | Description of the action performed at this stage | N° of articles |
| 1 | All articles containing the keywords | 128 |
| 2 | Title & abstract read selection | 49 |
| 3 | Full-text read selection | 37 |

Sources: Author’s elaboration

* 1. **Results and discussion**

The concept of digital agriculture is clearly defined in the literature (Duncan et al., 2022). Also called Agriculture 4.0 or smart farming is related to the design, development, and use of digital technologies in agricultural enterprises through processes that can develop and deliver advanced digital information to users (Benyam et al., 2021). It includes blockchain, the Internet of things (IoT), cloud, big data, and robots, enabling data collection to make decisions (Duncan et al., 2022).

Bahn et al. highlight the benefits of Digital agriculture, improving production performance, and making agricultural enterprises more efficient and inclusive(Bahn et al., 2021). Alongside these advantages, the benefits of impact generated in economics, sustainability, and traceability are still uncertain, as outlined above. The first literature review analysis is presented below to respond to these areas.

Table 2 identifies, for each area, the factors that characterize them. The factors are derived from a detailed analysis of the literature. The table identifies, for each author, the factors that characterize the study, showing that some factors cut across the three Areas. The factors that crosscut the Areas are cross-sectional factors (Poponi et al., 2022). The cross-sectional factors are productivity, resilience, data analysis, and transparency. The remaining factors identified are independent and present in only one aspect.

**Table 2. Matrix of Areas and key factors**

|  |  |
| --- | --- |
|  | Area |
| Factor | Competitiveness | Sustainability | Safety |
| Productivity | (Amentae & Gebresenbet, 2021; Bahn et al., 2021; Benyam et al., 2021; Birner et al., 2021; da Silveira et al., 2021; Erdoğan, 2022; Gangwar et al., 2020; Lioutas et al., 2021; Oruma et al., 2021; Prause et al., 2021; Reisman, 2021; Scuderi et al., 2022; Zhichkin et al., 2021) | (Amentae & Gebresenbet, 2021; Bahn et al., 2021; Benyam et al., 2021; Bhat & Huang, 2021; Duff et al., 2022; Duncan et al., 2022; Friha et al., 2021; Jambrak et al., 2021; Khan et al., 2021; Neethirajan & Kemp, 2021; Schnebelin et al., 2021) |  |
| Financial stimulus | (Bahn et al., 2021; da Silveira et al., 2021; Duncan et al., 2022; Eberhard et al., 2021; Scuderi et al., 2022) |  |  |
| Data analysis | (Bahn et al., 2021; Duncan et al., 2022; Friha et al., 2021; Monteleone et al., 2020; Reisman, 2021) | (Bertoglio et al., 2021; Khan et al., 2021) | (Adamashvili et al., 2021; Neethirajan & Kemp, 2021; Reisman, 2021; Scuderi et al., 2022) |
| Access to market | (Oruma et al., 2021) |  |  |
| Economic of scale | (Birner et al., 2021) |  |  |
| Open Innovation | (Birner et al., 2021; Grieve et al., 2019) |  |  |
| Type of production  | (Birner et al., 2021) |  |  |
| Organizational aspect | (Birner et al., 2021) | (Garske et al., 2021; Prause et al., 2021) |  |
| Complementary | (Birner et al., 2021) |  |  |
| External shock | (Galaz et al., 2021; L. Tan, 2016) |  |  |
| Capabilities | (Balogh et al., 2021; Grieve et al., 2019; Neethirajan & Kemp, 2021; Oruma et al., 2021) |  |  |
| Support | (Bahn et al., 2021; Oruma et al., 2021; Rijswijk et al., 2021) |  |  |
| Resilience | (Bahn et al., 2021; Galaz et al., 2021; Oruma et al., 2021; Reisman, 2021; Rijswijk et al., 2021) | (Duff et al., 2022; Ozsahin & Ozdes, 2022) | (Oruma et al., 2021) |
| Accessibility | (Bahn et al., 2021; da Silveira et al., 2021) |  |  |
| Footprint |  | (Bahn et al., 2021; da Silveira et al., 2021; Duff et al., 2022; Finger et al., 2019; Jambrak et al., 2021; Remondino & Zanin, 2022; Scuderi et al., 2022) |  |
| Waste |  | (Bertoglio et al., 2021; Collart & Canales, 2022; Glaros et al., 2022; Jambrak et al., 2021; Remondino & Zanin, 2022) |  |
| Environmental responsibility |  | (Duncan et al., 2022; Garske et al., 2021) |  |
| Pollution |  | (Garske et al., 2021; Scuderi et al., 2022) |  |
| Biodiversity |  | (Bahn et al., 2021; Green et al., 2021) |  |
| Transparency |  | (Green et al., 2021) | (Adamashvili et al., 2021; Bahn et al., 2021; Finger et al., 2019; Friha et al., 2021; Galaz et al., 2021; Neethirajan & Kemp, 2021) |
| Quality |  |  | (Adamashvili et al., 2021; Bahn et al., 2021; Finger et al., 2019; Friha et al., 2021; Reisman, 2021; Scuderi et al., 2022) |
| Partnership |  |  | (Adamashvili et al., 2021; Collart & Canales, 2022) |
| Integration business process |  |  | (Collart & Canales, 2022) |

Source: Author’s elaboration

* + 1. *Competitiveness area*

The first area investigated includes enabling or critical factors that impact competitiveness through the adoption of digital technologies.

The first factor is *productivity*. Data analysis, through digital technologies, on production quality, yields, and prices enables increased profits through better farm management (Bahn et al., 2021; da Silveira et al., 2021; Friha et al., 2021; Gangwar et al., 2020; Lioutas et al., 2021; Scuderi et al., 2022).

This factor directly influences *accessibility*, where the use of technology and machinery and the sharing of resources through new business models contribute to improving the company's competitiveness.

Amentae et al. (2021) state that enterprises using digital technologies must be profitable for the entire organization and seek to improve not only the internal environment but also the environment outside the enterprise (Amentae & Gebresenbet, 2021). There is a need for targeted policies and support for infrastructure and subsidies for purchasing and developing facilities, as well as increased training and education of human capital to stimulate digitization in enterprises. Through these activities, agricultural enterprises improve their efficiency and performance, meet demands, and make organizations more profitable with sustainable operations.

Another factor identified is *financial stimulus*, which according to Scuderi and Bahn et al. (2021), includes the financial tools available to companies to introduce innovations (Bahn et al., 2021; Scuderi et al., 2022), seeking to generate an economic return for investors (Bahn et al., 2021; Duncan et al., 2022). For Da Silveira et al. (2021), companies must use investments to adopt technologies, considering possible limitations (da Silveira et al. 2021).

Another factor identified is *market access* to guarantee agricultural production placed on the market. Proximity to food distributors or loading centers can ensure a continuous food supply and reduced waste for easily perishable products, especially when supply chains are under pressure, such as when foreign supplies are blocked, or in more critical situations, such as pandemics (Oruma et al., 2021).

Open innovation is described as the use of internal and external flows to increase internal innovation within a company (Chesbrough, H.W, 2003), enabling networking and generating numerous benefits for companies (Arcese et al., 2015). Open innovation techniques need to be supported by benchmarking, account management, and developing a change mindset (Birner et al., 2021; Grieve et al., 2019).

Moreover, it has been shown in the literature that farmers' adoption of digital technologies is negatively affected by the *external shock* factor (T. Tan et al., 2021). These shocks are external to companies and the economy, related to regulations and policies that drive the industry and the market, creating uncertainty and instability and making it difficult to adopt new technologies. According to Galaz et al. (2021), climate and environmental risks represent external situations that can limit profitability and increase costs, but thanks to digital technologies, the risks can be mitigated (Galaz et al., 2021).

The adoption of digital technologies is closely linked to the *Capabilities and Support* factors necessary to adopt and use new technologies. Many companies have difficulties adopting digital tools due to the lack of capabilities to use such technologies. The complexity of managing and using digital tools leads companies to request external support. The need to consult experts to support these new technologies is considered a cost with a negative economic impact rather than an opportunity to increase company performance (Rijswijk et al., 2021). Thus, the adoption of digital technologies is negatively mediated by *Capacity and Support factors*, which generate, in addition to costs, dependence on actors outside the enterprise. Therefore, farmers do not immediately recognize the economic opportunities of adopting digital technologies (Balogh et al., 2021). This demonstrates the need to rely on external actors to adopt new practices and increase farm competitiveness. The inability to adapt generates inequalities and increases the economic and social gap in the sector (Neethirajan & Kemp, 2021). The adoption of digital technologies also has a positive economic impact on the resilience of the firm and its production system (Rijswijk et al., 2021). Resilience shows that digital technologies need to be integrated efficiently into companies to avoid the creation of resilient ecosystems (Galaz et al., 2021). Other factors identified are *data analysis*, a method to collect accounting data from farms, and economies of scale, to promote the use of digital technologies on farms to increase demand (Birner et al., 2021).

Further factors that economically influence the adoption of digital tools are *Economic scale*, *Type of production*, and *Organisational aspect*. The possibility of generating economies of scale in the mechanization and digitization of a production process enables cost reduction and facilitates the adoption of new technologies for agricultural enterprises (Birner et al., 2021). However, economies of scale depend on the size of the company, its management, and the type of products. A large enterprise with structured management can better amortize the costs incurred by the digital transition, and the type of products grown can be a key point to invest in (Birner et al., 2021). Products requiring similar technologies will allow a more profitable investment.

*Complementarity* factor proposes the transfer of digital technologies to other undeveloped countries and agricultural systems. Public-private partnerships may be able to address their respective market failures (Birner et al., 2021), while the *accessibility* factor represents a solution to reduce inequalities.

* + 1. *Sustainability area*

The Sustainability area includes all factors that have an impact on the environment. For Jambrak et al. (2021), Scuderi et al., and Duff et al., the use of digital technologies minimizes the carbon and water *footprint*, with the potential to run a more sustainable and efficient food production facility (Duff et al., 2022; Jambrak et al., 2021; Scuderi et al., 2022). Remondino et al. believe digital technologies improve environmental sustainability by reducing negative externalities and waste while optimizing resource use (Remondino & Zanin, 2022). Data analysis factors sharing and a monitoring system make it possible to increase the productivity of the production system (Khan et al., 2021) and depend on the full use of tools that manage sustainability (Garske et al., 2021). Indeed, enterprises using digital technologies can collect data to monitor and control carbon emissions, monitor, and estimate crops, use resources sustainably, detect diseases and pests, monitor weather conditions, to implement new good agricultural practices and safety standards (Amentae & Gebresenbet, 2021; Bhat & Huang, 2021; da Silveira et al., 2021; Duncan et al., 2022; Schnebelin et al., 2021).

Another factor identified is *resilience*, where digital technologies such as big data enable practical and scalable solutions for conserving natural resources (Bhat & Huang, 2021). Duff et al. state that the use of digital technologies increases the ecological and economic resilience of agrosystems (Duff et al., 2022), while for Ozsahin et al., resilience concerning the sustainability factor is due to seasonal mitigation that threatens the production of enterprises (Ozsahin & Ozdes, 2022).

The *environmental responsibility* factor allows the application of good practices to increase animal welfare and resource productivity (Neethirajan & Kemp, 2021). Several authors (e.g. Bahn et al., 2021; Friha et al., 2021) highlight the potential deriving from digital technologies to reduce resource use and ecological footprint, increase biodiversity, and increase productivity. At the same time, it can generate future threats to sustainability, resource availability, and food security, as stated by Lioutas (Lioutas et al., 2021).

The last factor identified is *pollution*. Adopting digital tools enables businesses to reduce the impacts of production on the environment. This factor highlights how numerous and diverse the impacts of agricultural enterprises are and how it is necessary to act with a systemic approach to reduce the pollution caused. Following Scuderi et al. approach, it is necessary to define new methodologies or techniques of production to reduce pollution caused by agricultural enterprises (Scuderi et al., 2022).

* + 1. *Safety area*

The last area identified is *Safety* and includes the issue of traceability and food safety of agricultural enterprises.

One factor identified is the *transparency* of agricultural enterprises ensuring knowledge of product traceability by making all information available (Finger et al., 2019; Galaz et al., 2021). Creating a transparent production system allows for the dissemination of production system information. Consumers demand more transparency and sharing of information regarding animal welfare or the quality of raw materials used (Neethirajan & Kemp, 2021).

*Resilience* is also a factor of interest in safety. Oruma et al. (2021) highlight that the use of digital technologies in agricultural production is a viable option for achieving food security in a country facing serious challenges population growth, climate change, and restrictions associated with pandemics such as Covid-19. On this basis Monteleone et al. (2020) ascertain the presence of different methods (such as automation, robotics, IoT, and sensing technologies) to be used for the production needs of the company (Monteleone et al. 2020).

Another factor identified concerns *data analysis*. According to Reisman (2021), through data analysis, safety is ensured by platforms designed to record, store, and process data on agricultural products at every stage of relations between farms and retailers (Reisman 2021).

Another important factor is *quality*. For Oruma et al. (2021) digital technologies in food production allow to achieve food security, providing high levels of quality are guaranteed. Using sensors, blockchain, and digital platforms increases the security of production chains by making information more transparent, contributing to a higher quality of the production system (Bahn et al., 2021; Friha et al., 2021).

For some authors, the *partnership* factor promotes ecosystem development with digital technologies contributing to involving all actors in the production chain (Adamashvili et al., 2021; Collart & Canales, 2022),

Finally, the last factor identified is *business process integration*, where according to Collart et al., digital technologies are integrated into the most suitable production processes, depending on the desired results (Collart & Canales, 2022). By integrating business processes, companies can ensure that all systems work together toward expansion. During process improvement initiatives, many business owners find that they can better manage their operations by integrating existing systems.

* 1. **Conclusion**

# Through a critical literature review, the study aims to identify the key factors acting on the economic, security, and sustainability areas in adopting digital tools. The identified factors have different influence in the adoption of digital technologies. Some of them are enabling factors. Others limit the adoption of these technologies by agricultural enterprises. Some factors can influence all three areas investigated, for this reason they are defined cross-sectional, and are: productivity, resilience, data analysis, and transparency. The future research will combine these key factors to create a model to explain their impact on the agricultural enterprises.

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