How to cite: Barki, K. & M. A. Rachmah, 2024. Systematic literature review: Agricultural digitalization, technological transformation towards efficient and sustainable agriculture. Ege Univ. Ziraat Fak. Derg., 61 (2): 259-271, https://doi.org/10.20289/zfdergi.1382916

Review Article
(Derleme Makale)

Ege Üniv. Ziraat Fak. Derg., 2024, 61 (2):259-271
https://doi.org/10.20289/zfdergi.1382916

Systematic literature review*:* Agricultural digitalization, technological transformation towards efficient and sustainable agriculture

Sistematik literatür taraması: Tarımsal dijitalleşme, verimli ve sürdürülebilir tarıma doğru teknolojik dönüşüm

Khotimatul BARKI [1*]

Malinda Aptika RACHMAH [2]

[1] Diponegoro University, Faculty of Agriculture and Animal Science, Department of Agricultural Business, 50272, Semarang, Central Java, Indonesia

[2] Jendral Soedirman University, Faculty of Agriculture, Department of Agricultural Business, 53122, Purwokerto, Central Java, Indonesia

*Corresponding author (Sorumlu yazar):

khotimatulbarki@students.undip.ac.id

Alınış (Received): **30.10.2023** **Kabul Tarihi** (Accepted): **23.05.2024**

ABSTRACT

Objective: The objective of this study was to utilize a literature review and the PRISMA methodology. Analyzing how agriculture can alleviate the world's food problems is crucial. The application of digital platforms, artificial intelligence, and sensors, with a strong emphasis on innovation and digitalization, provides tangible evidence of the impact of digital agriculture.

Materials and Methods: This study comprehensively analyzes existing studies. Specific attention is given to policies encouraging digital technology adoption in agriculture, assessing challenges, studying policies from developed and developing nations to synthesize findings.

Results: By the use of IoT, big data analytics, and AI, digital technology improves sustainability, productivity, and efficiency in agriculture. Benefits for both developed and developing countries are acknowledged, but issues like training and access continue. Legislators must enact laws and take other measures to foster favorable conditions. Digital technology adoption increases productivity and decision-making, but it also creates privacy issues. Infrastructure, education, and data protection should be the main focuses of government policy in order to promote fair and sustainable agricultural development.

Conclusion: Adopting digital technology in agriculture on a large scale and improving global sustainability and efficiency require effective legislation. To advance the industry, recommendations include incorporating technical advancements into Indonesian agriculture laws based on successful worldwide experiences.

Keywords: Agricultural, digital, IoT, policy, technology

ÖZ

Amaç: Bu çalışmanın amacı literatür araştırmasının yapılması ve PRISMA yönteminin kullanılmasıdır. Araştırma, dijital platformların, sensörlerin ve yapay zekanın tarım üzerindeki etkilerine özel bir vurgu yaparak, dijital teknolojilerin küresel gıda güvenliği sorunlarını çözmede oynadığı rolü incelemektedir.

Material ve Yöntem: 30 makalenin analizi araştırmanın temelini oluşturmuştur. Araştırma kriterleri titizlikle uygulandı ve sonuçlar PRISMA kılavuzlarına uygun olarak metodik olarak birleştirildi.

Araştırma Bulguları: Nesnelerin İnterneti (IoT), büyük veri ve yapay zeka gibi dijital teknolojiler, mahsullerin hayatta kalmasını, üretkenliğini ve başarısını artırmasını sağladı. Araştırmaya göre, bu teknolojiler hava durumu, toprak kontrolü ve haşere kontrolü için kullanılabilir. Gelişmiş ülkelerde uygulanmasında eğitim eksikliği ve erişim eksikliği gibi sorunlarla karşılaşılmaktadır. Dijital tarım, uygun politikalarla desteklendiğinde mahsul verimini, kaynak verimliliğini ve karar alma süreçlerini iyileştirmek için büyük bir potansiyele sahiptir. Bu nedenle, veri güvenliği, eğitim ve altyapı politikaları çok önemlidir.

Sonuç: Dijital tarım, kaynak verimliliğini, mahsul verimini ve karar alma süreçlerini iyileştirebilir, ancak bunu başarmak için uluslararası işbirliği ve uygun politika taahhütleri gereklidir.

Anahtar sözcükler: Tarım, dijital, IoT, politika, teknoloji

INTRODUCTION

The goal of ensuring food security on a worldwide scale has become more difficult in recent years due to the growing global population and the increasing impact of climate change on agricultural production. In response to these challenges, there is a growing interest in finding new ways to address the global food crisis and support sustainable agriculture. Meeting the increasing nutritional needs of the population is essential for agriculture, which is the foundation of many economies. Conventional farming methods face several problems, including declining natural resources, increased efficiency, and resource limits. With populations increasing worldwide and the impact of climate change on agricultural productivity, the challenge of ensuring food security worldwide is increasingly becoming difficult (FAO, 2020). Therefore, it is imperative to investigate new approaches to support sustainable agriculture and address the global food crisis (FAO, 2021). Agriculture is essential to meeting the nutritional needs of a growing population because it is the basis of many economies (FAO, 2019). However, conventional farming methods face a number of problems, such as reduction of natural resources, increased efficiency, and limited resources (Çakmakçı et al., 2023). In agriculture, artificial intelligence (AI), digital technologies, and sensor-based solutions have been the path to progress in response to these challenges (Oliveira et al., 2023). The rise of sensors, digital platforms and artificial intelligence has transformed agricultural operations by improving production, accuracy and sustainability (Sharma et al., 2023). Developed countries made great progress in integrating this technology into their agricultural systems to demonstrate its potential benefits for small and large-scale agricultural operations. However, despite these advances, there is still a lack of knowledge on how these innovations can be used effectively in developing countries, where agricultural practices are often characterized by various difficulties, such as limited access to technology (Dhanaraju et al., 2022).

In agriculture, there has been a major shift towards the integration of digital technology, artificial intelligence, and sensor-based solutions. These technologies have demonstrated the capacity to transform agricultural operations by improving sustainability, production, and accuracy. While developed countries have made great progress in integrating this technology into their agricultural systems, they still do not understand how this innovation can be used in developing countries. Developing countries often face problems such as limited access to technology, scattered land tenure, and insufficient infrastructure. Policies that encourage the use of digital technology in agriculture have become popular around the world, showing that more and more people are realizing how important a paradigm shift is in agricultural engineering.

The success of these policies varies, and a deeper understanding of effective techniques that can be applied in a variety of agricultural contexts in both developed and developing countries is required, as they enable farmers to adopt digital solutions and increase productivity while using fewer resources and producing higher yields. Policies that encourage the use of digital technologies in agriculture have become popular around the world, showing how important it is to change the paradigm of agricultural engineering (FAO, 2019). Farmers should be able to adopt digital solutions and increase productivity while using fewer resources and yielding higher yields with the help of these rules (Konfo et al., 2023). Although the success of these policies varies, future agricultural development projects must be driven by knowledge of effective techniques. This study looks at the benefits of implementing digital technologies in agriculture across the board and examines the impact of policies in developed and developing countries. The purpose of this study is to increase current knowledge. In addition, the study recognizes how important it is to address the challenges associated with incorporating digital technologies. This study ensures that these advances can be obtained and benefit many agricultural practitioners (Mikhailov et al., 2022). To improve agricultural sustainability, it is important to achieve the Sustainable Development Goals (SDGs) (FAO, 2018). This goal can be achieved by digital agriculture by producing more with less environmental impact (Hrustek, 2020).

The study conducted will address global issues, innovative solutions, and the use of digital platforms, artificial intelligence, and sensors in agriculture to build a resilient and sustainable future. This is because digital agriculture has the potential to produce more results with less environmental impact. Therefore, this research aims to enhance the current knowledge base to create a resilient and sustainable future by thoroughly examining the benefits of applying digital technologies in agriculture. The study intends to provide insights into effective methods and recognize the importance of solving difficulties related to the integration of digital technology by studying the effects of policies across different agricultural settings. Furthermore, the objective is to provide significant perspectives on the capacity of digital technology to tackle sustainability issues in agriculture, including improving resource efficiency, reducing climate change, and guaranteeing food security. The goal of the study is to provide useful suggestions for the efficient application of digital technology in various agricultural contexts by analyzing case studies and best practices from industrialized and developing nations. It will also go over how technical advancements are making it easier for traditional and contemporary farming practices to coexist, with an emphasis on how this is helping small-scale farmers in developing nations.

MATERIALS and METHODS

This study was carried out in order to perform a literature review that can be used as a resource in descriptive and explanatory research. Using a narrative systematic review approach, specifically the Systematic Literature Review (SLR) method with Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guidelines, this study identified and analyzed relevant research topics in descriptive-based studies that addressed current and interesting issues. The Systematic Literature Review approach, along with the PRISMA methodology, permitted a thorough search and screening of relevant publications. To find papers that aligned with the study aims, the established inclusion and exclusion criteria were strictly implemented. This study contained 30 papers and the findings were methodically arranged and presented in accordance with the PRISMA criteria. The PRISMA technique aided in the methodological arrangement and presentation of the findings of the review. This comprehensive strategy aims to increase knowledge on the subject by integrating information from a broad selection of 30 papers that satisfied the established criteria. It can be stated that this study contributes to the body of knowledge in the field by using a narrative systematic review technique and adhering to the PRISMA principles, providing a useful resource for future descriptive and explanatory investigations. The following is a list of 30 articles used in this study with the PRISMA method as follows:

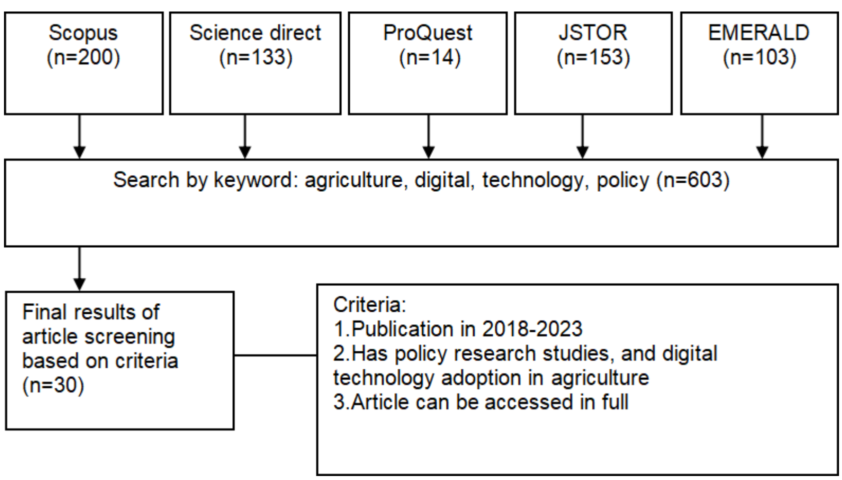

Figure 1. PRISMA method.

Şekil 1. *PRISMA yöntemi.*

RESULTS and DISCUSSION

Number and Type of Publications

Several academic studies investigated the influence of incorporating digital technology into agriculture on agricultural policies. Researchers, institutes, governmental entities, and numerous organizations have been actively studying the use of digital technology in agriculture. The link between the incorporation of digital technology in agriculture and its alignment with government policy goals related to agribusiness and agricultural development is a recurring subject of this study. Notably, a temporal analysis based on the publication year classification revealed an increasing tendency in research effort. According to classification by year of publication, many studies showed that the adoption of digital technologies in agriculture supports government policy programs related to agribusiness and agricultural development. Studies conducted over the past five years were in 2018 (10%), 2019 (10%), 2020 (17%), 2021 (17%), 2022 (37%), and 2023 (10%) as shown in Table 1.

Table 1. Number of studies as published by the year of publication

***Çizelge 1**. Yayın yılına göre araştırmalar ve sayılarır*

Year	Amount	Percentage (%)
2018	3	10
2019	3	10
2020	5	17
2021	5	17
2022	11	37
2023	3	10
		100

Source: Primary Research Data, 2023.

The authors' classification, as delineated by their affiliations, revealed a predominant representation from academic institutions, with 90% of the contributors affiliated with universities and colleges. This underscores the substantial involvement of scholars and academics in exploring the intersection between digital technology and agriculture, highlighting the keen interest of the academy community in this research domain. Additionally, the data indicated that 10% of the authors were associated with the research sector reflecting the engagement of professionals and experts from non-academic research entities. This diversity in authorship affiliation suggests a collaborative effort between academia and the broader research sector to address the multifaceted implications of integrating digital technology into agricultural practices comprehensively. The juxtaposition of these affiliations underscores the interdisciplinary nature of research, as both academic and research sector perspectives contribute to a holistic understanding of the complex dynamics between digital technology and agricultural policy as shown in Table 2.

Table 2. Author affiliation

***Çizelge 2.** Yazar bağlantıları*

Affiliation	Amount	Percentage (%)
University	27	90
Researcher	3	10
		100

Source: Primary Research Data, 2023.

Research on digital technology in agriculture relies on diverse sources, with 13% from e-journals and a significant 37% from research findings. Half of the papers conduct thorough reviews of previous studies, emphasizing knowledge synthesis. Conceptual papers constitute 81%, empirical research 19%, and case studies 11%, all maintaining methodological rigor. Methodologies consist of surveys (20%), case studies (55%), and regression analysis (14%). Additional techniques like Structural Equation Modeling (SEM) (2%), NVIVO (5%), and Partial Least Squares (PLS) (2%) were also utilized, showcasing methodological diversity.

Geographically, the research landscape spans both developing and developed countries over the past five years, predominant 70% of research articles originating from developed nations. Notable contributors included China (20%), the USA (20%), Germany (10%), France (3%), Greece (3%), Australia (3%), Taiwan (3%), the UK (3%), and Japan (3%). Developing countries accounted for 30% of the research output, with contributions from Russia (7%), Ukraine (3%), Philippines (3%), Indonesia (3%), India (10%), and Kenya (3%) (see Table 3 for a detailed breakdown). This global distribution underscores the widespread interest and engagement of countries across different levels of economic development in exploring the intersection between digital technology and agriculture as shown in Table 3.

Table 3. Country distribution of research publications

Çizelge 3. *Ülkelere göre araştırma yayınlarının dağılımı*

	Amount	Percentage (%)
Developed Countries		
China	6	20
US	6	20
Germany	3	10
France	1	3
Greece	1	3
Australia	1	3
Taiwan	1	3
UK	1	3
Japan	1	3
Developing Countries		
Russia	2	7
Ukraine	1	3
Philippines	1	3
Indonesia	1	3
India	3	10
Kenya	1	3
		100

Source: Primary Research Data, 2023.

Digital Technology in Agricultural Development

Digital technologies have great potential to accelerate agricultural growth and increase productivity. As it can improve the productivity, efficiency, and sustainability of the agricultural sector, digital technology is essential for agriculture (Gabriel & Gandorfer, 2023). Based on the statement of Zhong et al. (2021), digital technologies such as mobile agricultural applications, AI, big data analytics, blockchain, and IoT can be used for weather monitoring, soil management, pest management, and animal health monitoring. In addition, digital technologies have the potential to improve the market, strengthen the link between the agricultural sector and information and communication technology, and enhance the capacity of farmers. Therefore, to increase the productivity and sustainability of the agricultural sector, the government and the agriculture industry must support the spread and adoption of technology in the agricultural sector. Overall, the use of digital technologies in agriculture can help farmers improve productivity, efficiency, and yield quality of agricultural products. This promotes more sustainable agriculture and contributes to global food security (Lioutas et al., 2021).

Digital agriculture has been used by both developed and developing countries to achieve agricultural development goals. Some of the digital technologies include big data technology to improve crop monitoring data, supply chain coordination, and sustainability metrics, as well as distributed ledger technology (DLT) to change the roles of stakeholders in the agricultural supply chain. In agriculture, big data technologies can be used to improve the quality of crop monitoring data, sustainability metrics and supply chain coordination. By collecting and analyzing data from various sources, big data technology can provide insights into crop growth patterns, soil quality, weather patterns, and other elements that affect agricultural production (Jayashankar, 2020). Reducing waste, improving sustainability, and increasing crop yields can be achieved using this data. In addition, big data technologies can be used to coordinate the supply chain from farm to market by providing information on inventory levels, demand, and prices in real time. Farmers can use algorithms and data analytics techniques to collect and analyze farm data so that they can understand trends, patterns, and variability in their production. Using algorithms and data analytics techniques, farmers can make crop forecasts, import more crops, and increase yields. Agricultural technology providers can decide how to make the co-creation process more beneficial for farmers. Technology providers also can create the right technology tools that help farmers understand crop management. Agricultural stakeholders can learn how to create big data analytics tools and marketing narratives to maximize value and prevent value destruction (Griffin, 2022).

Additionally, some developed countries have used artificial intelligence technologies such as Artificial Intelligence AI to support agricultural development. Farmers can develop prediction models with artificial intelligence and machine learning to anticipate weather changes, forecast harvest levels, and optimize agricultural risk management (Garske, 2021), new cloud-based Internet of Things (IoT) systems to monitor livestock health parameters, such as stress levels, body temperature, movement recognition, and heart rate, as well as environmental metrics such as relative humidity levels and air temperature. In addition, livestock and their owners can be electronically identified through ear tags used with smart cards and UIDs (Saravanan & Saraniya, 2018). Farmers can also monitor and control farm conditions in real-time with IoT connected sensors and devices. For example, they can measure temperature, humidity, soil pH, and air quality in the farm field. This data can help make better decisions about what to do, such as fertilizing, watering, or protecting crops against pests and diseases (Wang et al., 2020). The development of digital villages and the use of digital technologies in China to promote sustainable agriculture are also reported to have a positive impact on the progress of the sector (Wang &Tang, 2023). Digital technologies in agriculture can improve productivity, efficiency, and sustainability. However, it is important to consider that these technologies are accessible to all farmers, that the necessary infrastructure is in place, and that farmers must receive the necessary training and instruction to utilize them effectively. All of these can work together to improve the efficiency of agricultural production and help farmers make better choices (Kumar & Basu, 2022).

E-agriculture or agricultural digitalization is a pillar of agricultural and rural development (Ugochukwu & Phillips, 2017). The adoption of digitalization in agriculture provides great benefits to agricultural productivity due to its potential to support sustainable agricultural development, digital agricultural technology has attracted a lot of attention because it can improve agricultural sustainability, productivity and efficiency (Kashina et al., 2022; Zhu et al., 2023). Research conducted by Kitole et al. (2024) shows that digitalization of agriculture can increase agricultural production in Tanzania, in the study it was found that 78% of farmers agree that digitalization of agriculture can reduce risk and uncertainty, 74.75% of farmers stated that digitalization has made it easier for them to access capital/money, so that farmers' income can increase. However, on the other hand, Kitole et al. (2024) in their research found that the adoption of digital technology among smallholders in Tanzania was influenced by household income. This shows that a high level of income will certainly be easier to access agricultural digitalization because it has the resources to invest (Sanga et al., 2014; Rotondi et al., 2020; Subramanian, 2021). Therefore, support from various parties, especially the government, is needed in encouraging the transformation of agricultural digitalization. Abdulai (2022) also stated that digitalization of agriculture has an impact on increasing productivity, profitability, and is able to reduce the risk/uncertainty of climate change that is often felt by smallholders. Digitalization of agriculture is a source of strength to increase rural incomes, food security and national economy because it encourages farmers to make the right decisions and be able to connect small-scale farmers to consumers or more profitable markets (Keogh & Hendry, 2016; Mushi et al., 2022; Kitole et al., 2023).

Digital farming has been used in a variety of contexts and demonstrates the ability to transform agricultural practices. Case studies have shown how digitalization impact agriculture in different regions. For example, the spatial distribution of Freshippo village in China shows the adoption of sustainable digital farming practices (Peng et al., 2023). In Nigeria, a review of agricultural digitalization shows the country's efforts to adopt digital technologies in agriculture (Izuogu et al., 2023). Furthermore, the "Africa Goes Digital" case emphasizes the development of communities of practice consisting of companies founded by youth engaged in agriculture through digitalization, affirming the important role played by youth in African agriculture (Ayamga et al., 2023). Case studies using the latest technology in the digital management of agriculture in Romania showed the progress the country has made in digitizing its agricultural practices. In addition, the influence of the digital economy on the growth of high-quality specialty farmer cooperatives in China demonstrates the potential of digital technology transformation in agricultural cooperatives (Liu & Zhang, 2023). These case studies collectively show the different ways digital agriculture is used and its impact in different regions, showing how it can help develop sustainable agriculture.

In agriculture, the Internet of Things (IoT) is growing in popularity, transforming traditional farming methods and supporting sustainable growth. IoT implementation in agriculture includes the use of interconnected sensors and devices to collect and transmit data, allowing farmers to optimize various aspects of agricultural production and make data-driven decisions. According to Ciruela-Lorenzo et al. (2020), Automated systems using Internet of Things (IoT) technology have been created to monitor and control agricultural processes. For example, in Europe, the "Internet of Food and Farm 2020" demonstrates the integration of the Internet of Things throughout the supply chain, from logistics and processing to field operations. As a result, an olive farming cooperative developed an "automatic olive chain".

Sugarcane farming communities have been using the Internet of Things through wireless sensor networks connected by Internet of Things technology. This enables a network of automated rainfall gauges and data collection to support better decision-making (Fielke et al., 2021). In addition, it is proven that the Internet of Things (IoT) has the ability to improve the efficiency and sustainability of resources. IoT sensors and remote sensing can improve technical efficiency, business performance, and agricultural sustainability (Garske et al., 2021). In addition, it has been proven that the ever-increasing digital transformation of agriculture facilitated by IoT systems increases farmers' production efficiency and the quality of agricultural products, which in turn results in an increase in farmers' incomes (Zhang & Fan, 2023). In addition, the Internet of Things has played an important role in encouraging environmentally friendly livestock management, assisting animal welfare, and supporting sustainable agricultural practices (Rolandi et al., 2021). The use of IoT in farm management can improve animal welfare and support sustainable agricultural practices. Overall, it has been proven that the use of the Internet of Things (IoT) in the agricultural industry has the ability to encourage sustainable agricultural practices, improve resource efficiency, and improve decision-making processes. Ultimately, this will result in progress in the agricultural industry.

The digital transformation of agriculture has many benefical aspects but it also brings unacceptable impacts and several problems. Digital agricultural transformation will reduce human labor so that it will have an impact on increasing unemployment (Carlon, 2008). The use of digital agricultural technology will also create a gap between traditional farmers and modern farmers and will cause problems of inheritance of traditional agricultural culture that is environmentally friendly for young farmers (Lobley et al., 2018;

Burton et al., 2008). An example of the adverse impact of digital transformation is that machines replace labor in China, even though agriculture in China provides jobs for 194.45 million people, mainly living in rural areas (National Bureau of Statistics of China, 2019). In addition, digital transformation has an impact on weak data privacy and security. In China, some farmers are not aware of cyber threats such as data theft, accessing sensitive data, and so on (Xie et al., 2021). Therefore, special attention is needed in the social and political implications caused by the digital transformation of agriculture.

Agricultural Policy towards Digital Technology Adoption

Considering the advances in digital technologies that have been implemented in several developed and developing countries, it is clear that policies that support the adoption of digital technologies in the agricultural sector are an important step towards innovation, increased productivity and sustainability. Digital technology has transformed the world of agriculture by offering effective and real-time data-driven solutions to farmers' problems. Appropriate policies are still needed to encourage the adoption of digital technologies in agriculture. One important step towards innovation, increased productivity, and sustainability of the agricultural sector is a policy that supports the adoption of digital technology. With good technology infrastructure, adequate education and training, adequate funding, data and privacy protection, and intensive research, farmers will be able to adopt digital technologies successfully and utilize them to increase yields, reduce losses, and produce better products. Policymakers should think of ways to reach out to farmers and the agriculture industry. The agriculture industry can use digital mobile-based interfaces to support the adoption of these technologies.

Supportive government regulations and policies should favor the adoption of these technologies in the agricultural sector. To combat low productivity and poverty, the agricultural sector must build and strengthen its relationship with information and communication technologies in various areas, especially in agricultural production, improving markets, and building farmers' capacity. Mobile agriculture applications have been initiated by the Indian government and can now be used by farmers in many areas such as crop protection, weather monitoring, soil management, and pest management (Sharma et al., 2020). Kenya has implemented digital finance for farmers. Agribusiness risks will be reduced with the adoption of more financial services (Gopane, 2018). The agriculture sector also requires strengthening the workforce, especially in rural areas for technology adoption. Currently, the success of mobile agricultural applications depends on penetration into rural areas. Chuang et al. (2020) stated that when HR knowledge, perception, and behavior are good, the adoption of agricultural innovations will be successful.

Policy makers should consider ways to collaborate with local authorities and the agricultural industry to support digital mobile-based interfaces. To educate end users, agricultural science curricula should be enriched with information on advances in agricultural extension (Drewry et al., 2022). In addition, actions need to be taken to revive strategies to popularize mobile farming applications and their implications. Policies around the world have made the adoption of digital technologies and mobile devices in agricultural practices a top priority, so the implementation of smart agriculture with the use of smart technologies will be more quickly achieved (Gerli et al., 2022).

The government should concentrate on increasing the adoption of technology in the agricultural sector. The government can create policies to encourage the adoption of digital technologies, such as mobile apps for farmers, electronic identification for livestock, and the use of big data technologies to organize supply chains and monitor crops. In addition, the government can use digitalization to support the development of digital villages and promote sustainable agriculture. In addition, the government can establish policies to bridge the digital divide and encourage digital empowerment in rural areas, as well as to promote high-quality and environmentally friendly agricultural development. To encourage innovation in the agricultural sector, the government should create policies that support the adoption of digital technologies, such as artificial intelligence (AI), Internet of Things (IoT), and data analytics. These technologies can generate new efficient and sustainable solutions to address challenges in agricultural production.

Policies that support the adoption of these digital technologies will help developing and implementing these innovative solutions. Government policies that encourage farmers to use digital technologies can increase the productivity of the agricultural sector and improve crop monitoring and management as well as the quality and quantity of production. Digital technology can also improve the resilience and sustainability of the agriculture sector. Farmers can find and address issues before they become serious problems through accurate and real-time monitoring. In addition, digital technology can help in effective water management, proper fertilizer use, and disease and pest prevention. In addition to promoting sustainable agricultural practices, policies that support the adoption of digital technologies will increase the resilience of the agricultural sector to market fluctuations and climate change. Better financial management and agricultural information can be accessed through digital technology. Through digital platforms, farmers can find out market prices, the latest cultivation techniques, weather information, and business opportunities. Farmers can optimize their product sales, expand market reach, and make better decisions using digital technology. Government policies that encourage the adoption of digital technology will expand market opportunities and improve information accessibility. If agricultural enterprises are able to innovate technologically, they will have to compete with global competition. The government can play an important role in encouraging the adoption of digital technology by making the right policies.

CONCLUSION

In agriculture, the use of digital technology can significantly increase productivity, efficiency, and sustainability. Technologies such as the Internet of Things, big data analytics, and AI offer real-time solutions for livestock management, supply chain coordination, and crop monitoring. Although digitalization helps developed and developing countries, issues such as access and training still need to be addressed. Policymakers play an important role in creating a supportive environment through the implementation of supportive regulations and initiatives. In agriculture, the adoption of digital technologies can improve production, resource efficiency, and decision-making. However, this also raises issues such as privacy concerns and changes in agricultural systems. To ensure equitable profits and promote sustainable agricultural development, government policies should concentrate on infrastructure, education, and data protection.

ACKNOWLEDGMENT

The author expresses sincere gratitude to everyone who helped with this study, especially to Ege University for their invaluable help.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Author Contributions*

Conception and design of the study: KB, MAR; sample collection: KB, MAR; analysis and interpretation of data: KB; statistical analysis: KB, MAR; visualization: KB; writing manuscript: KB, MAR; writing, review and editing: KB.

Conflict of Interest

The authors state no conflict of interest.

Ethical Statement

We declare that there is no need for an ethics committee for this research.

Financial Support

The authors state no funding involved.

Article Description

This article was edited by Section Editor Dr. H. Ece SALALI.

REFERENCES

Ayamga, M., A. Lawani, S. Akaba & A. Birindwa, 2023. Developing institutions and inter-organizational synergies through digitalization and youth engagement in african agriculture: the case of “africa goes digital”. Land, 12 (1): 199. https://doi.org/10.3390/land12010199.

Bugayong, I. D., K. Hayashi, N.J V.B. Querijero , M.E.M. Orden, N. Agustiani, L. Hadiawati, I.H. Siregar, W.B. Carada & V.A. Atienza, 2019. Technology transfer pathways of information and communication technologies for development (ICT4D): the case of the weather-rice-nutrient integrated decision support system (werise) in Indonesia. Journal of The International Society for Southeast Asian Agricultural Sciences, 25 (2): 104-117.

Burton, R. J. F., C. Kuczera & G. Schwarz, 2008. Exploring farmers’ cultural resistance to voluntary agri-environmental schemes. Sociologia Ruralis Journal of the European Society for Rural Sociology, 48 (1): 16-37. https://doi.org/10.1111/j.1467-9523.2008.00452.x

Çakmakçı, R., M.A. Salık & S. Çakmakçı, 2023. Assesment and principles of environmentally sustainable food and agricultural systems. J. of Agriculture, 13 (5): 1073. https://doi.org/10.3390/agriculture13051073

Carolan, M. S., 2008. More-than-representational knowledge/s of the countryside: how we think as bodies. Sociologia Ruralis Journal of the European Society for Rural Sociology, 48 (4): 408-422. https://doi.org/10.1111/j.1467-9523.2008.00458.x

Chuang, J.H., J.H. Wang, Liou Y.C, 2020. Farmers’ knowledge, attitude, and adoption of smart agriculture technology In Taiwan. International Journal of Environmental Research and Public Health, 17 (19): 1-8. https://doi.org/10.3390/ijerph17197236

Ciruela-Lorenzo, A., A. Del-Águila-Obra, A. Meléndez & J. Plaza-Angulo, 2020. Digitalization of agri-cooperatives İn the smart agriculture context. Proposal of A Digital Diagnosis Tool Sustainability, 12 (4): 1325. https://doi.org/10.3390/su12041325.

Dhanaraju, M., P. Chenniappan, K. Ramalingam, S. Pazhanivelan & R. Kaliaperumal, 2022. Smart farming: internet of things (IoT)-based sustainable agriculture. Journal of Agriculture, 12 (10): 1745. https://doi.org/10.3390/agriculture12101745

Drewry, J.L., J.M. Shutske, D. Trechter, B.D. Luck, 2022. Assessment of digital technology adoption and access barriers among agricultural service providers and agricultural extension professionals. Journal of The ASABE, 65 (5): 1049 -1059. https://doi.org/10.13031/ja.15018

FAO, 2018. Sustainable development goals. Food and agriculture organization of the united nations. (Web page: https://www.fao.org/sustainable-development-goals/en/) (Date accessed : July, 2023).

FAO, 2019. The state of food and agriculture 2019. Food and agriculture organization of the united nations. (Web page: http://www.fao.org/3/ca5162en/ca5162en.pdf) (Date accessed : July, 2023).

FAO, 2020. The state of food security and nutrition in the world 2020. Food and agriculture organization of the united nations. (Web page: http://www.fao.org/3/ca9692en/ca9692en.pdf) (Date accessed : July, 2023).

FAO, 2021. Transforming food and agriculture to achieve the SDGs. Food and agriculture organization of the united nations. (Web page: http://www.fao.org/3/ca9692en/ca9692en.pdf) (Date accessed: July, 2023).

Fielke, S. J., R. Garrard, E. Jakku, A. Fleming, L. Wiseman & B.M. Taylor, 2019. Conceptualising the DAIS: implications of the ‘digitalisation of agricultural innovation systems’ on technology and policy at multiple levels. NJAS: Wageningen Journal of Life Sciences, 90 (1): 1-11.

Fielke, S., B. Taylor, E. Jakku, M. Mooij, C. Stitzlein, A. Fleming & M. Vilas, 2021. Grasping at digitalisation: turning imagination into fact in the sugarcane farming community. Sustainability Science, 16 (2): 677-690. https://doi.org/10.1007/s11625-020-00885-9.

Gabriel, A. & M. Gandorfer, 2019. Adoption of digital technologies in agriculture—an inventory in a european small-scale farming region. Precision Agriculture, 24 (1): 68-91. https://doi.org/10.1016/j.njas.2019.04.002

Garske, B., A. Bau & F. Ekardt, F, 2021. Digitalization and AI in european agriculture: a strategy for achieving climate and biodiversity targets?. Journal of Sustainability, 13 (9): 4652. https://doi.org/10.3390/su13094652

Gerli, P., J. Clement, G. Esposito, L. Mora & N. Crutzen, 2022. The hidden power of emotions: how psychological factors influence skill development in smart technology adoption. Technological Forecasting and Social Change, 180: 121721. https://doi.org/10.1016/j.techfore.2022.121721

Gopane, T., 2018. "What is the impact of digital financial service on agribusiness market risk? 1-7". in 2018 ist-africa week conference (IST-Africa). South Africa, University of Johannesburg, 1-7 pp.

Griffin, T.W., K.D. Harris, J.K Ward, P. Goeringer & J.A. Richard, 2022. Three digital agriculture problems in cotton solved by distributed ledger technology. Applied Economic Perspectives and Policy, 44 (1): 237-252. https://doi.org/10.1002/aepp.13142

Hrustek, L., 2020. Sustainability driven by agriculture through digital transformation. Sustainability Journal. 12 (20): 8596. https://doi.org/10.3390/su12208596

Huang, X., F. Yang & S. Fahad, 2022. The impact of digital technology use on farmers' low-carbon production behavior under the background of carbon emission peak and carbon neutrality goals. Frontiers in Environmental Science, 10: 1002181. https://doi.org/10.3389/fenvs.2022.1002181.

Izuogu, C., L. Njoku, M. Olaolu, P. Kadurumba, G. Azuamairo & G. Agou, 2023. A review of the digitalization of agriculture İn Nigeria. Journal of Agricultural Extension, 27 (2): 47-64. https://doi.org/10.4314/jae.v27i2.5

Jayashankar, P., W.J. Johnston, S. Nilakanta & R. Burres, 2020. Co-creation of value-in-use through big data technology- A B2B agricultural perspective. Journal of Business and Industrial Marketing, 35 (3): 508-523. https://doi.org/10.1108/JBIM-12-2018-0411

Kanna, M., 2021. Digital transformation of the agricultural sector: pathways, drivers and policy implications. Applied Economic Perspectives and Policy, 43 (4): 1221-1242. https://do.org/10.1002/aepp.13103

Kashina, E., G. Yanovskaya, E. Fedotkina, A. Tesalovsky, E. Vetrova, A. Shaimerdenova & M. Aitkazina, 2022. Impact of digital farming on sustainable development and planning in agriculture and increasing the competitiveness of the agricultural business. International Journal of Sustainable Development and Planning, 17 (8): 2413-2420. https://doi.org/10.18280/ijsdp.170808

Keogh, M. & M. Henry, 2016. The Implications of digital agriculture and big data for australian agriculture. Australian Farm Institute, Sydney, Australia, 1-84 pp.

Kitole, F. A., E. Mkuna, and J.K. Sesabo, 2024. Digitalization and agricultural transformation in developing countries: empirical evidence from tanzania agriculture sector. Smart Agricultural Technology, 7 (2024): 100379. https://doi.org/10.1016/j.atech.2023.100379

Kitole, F., R. Lihawa, J. Sesabo & C. Shitima, 2023. The dynamism of communication technology adoption, market information and welfare: evidence from nile perch (lates niloticus) fish market, Mwanza, Tanzania, Lake. Journal of Lake & Reservoirs Research & Management, 28 (1): 1-13. https://doi.org/10.1111/lre.12433.

Kondratiev, V. (2018). Global value chains, industry 4.0 and industrial policy. Journal of The New Economic. 9 (3): 170-177. Doi: https://doi.org/10.31737/2221-2264-2018-39-3-11

Konfo, T.R.C., F.M.C. Djouhou, M.H. Hounhouigan, E. Dahouenon-Ahoussi, F. Avlessi & C.K.D. Sohounhloue, 2023. Recent advances in the use of digital technologies in agri-food processing: a short review. Applied Food Research, 100329. https://doi.org/10.1016/j.afres.2023.100329

Korotchenya, V., 2019. Digital agriculture and agricultural production efficiency: exploring prospects for Russia. J. Espacios, 40 (22): 22-35.

Kumar, A. & S. Basu, 2022. Can end-user feedback inform 'responsibilisation' of India's policy landscape for agri-digital transition?. Sociologia Ruralis, 62 (2): 305-334. https://doi.org/10.1111/soru.12374

Lioutas, D., C. Charatsari. M.D. Rosa, 2021. Digitalization of agriculture: a way to solve the food problem or a trolley dilemma?. Technology In Society, 67 (2021): 101744. https://doi.org/10.1016/j.techsoc.2021.101744.

Liu, X. and Zhang, X., 2023. The impact of the digital economy on high-quality development of specialized farmers' cooperatives: evidence from China. Sustainability Journal, 15 (10): 7958. https://doi.org/10.3390/su15107958.

Lobley, M., R. Winter, and R. Wheeler, 2018. The changing world of farming in brexit UK (Perspectives on Rural Policy and Planning). CRC Press: Routledge, UK, 262 pages.

Maurel V.B., E. Lutton, P. Bisquert, L. Brossard, S. Chambaronginhac, P. Labarthe, P. Lagacherie, F. Martignac, J. Molena, N. Parisey, S. Picault, S. Piot-Lepetit & I. Veissier, 2022. Digital revolution for the agroecological transition of food systems: a responsible research and innovation perspective. Journal of Agricultural Systems, 203 (2022): 103524. https://doi.org/10.1016/j.agsy.2022.103524.

Mikhailov, A., G.F. Camboim, F.M. Reichert & P.A. Zawislak, 2022. The application and benefits of digital technologies for agri-food value chain: evidence from an emerging country. RAM. Revista de Administração Mackenzie, 23 (5): 1-29. https://doi.org/10.1590/1678-6971/eramr220114.en

Mushi, G. E., G.D.M. Serugendo, and P-Y Burgi, 2022. Digital technology and services for sustainable agriculture in Tanzania: a literature review. Sustainability Journal, 14 (4): 1-1. https://doi.org/10.3390/SU14042415.

National Bureau of Statistics of China, 2019. Number of employed persons by three industries. (Web page: https://data.stats.gov.cn/easyquery.htm?cn=C01) (Date accessed: January, 2024).

Novak, I.M., O.Y. Ermakov, O.A. Demianyshyna & Revytska, 2020. Digitalization as a vector of technological changes of Ukraine. International Journal of Scientific and Technology Research, 9 (1): 3429-2434.

Oliveira, R.C.D. & R.D.D.S.E. Silva, 2023. Artificial intelligence in agriculture: benefits, challenges, and trends. Applied Sciences, 13 (13): 7405. https://doi.org/10.3390/app13137405

Peng, X., G. Wang & G. Chen, 2023. Spatial distribution of freshippo villages under the digitalization of new retail in china. Sustainability, 15 (4): 3292. https://doi.org/10.3390/su15043292.

Prause, L., 2021. Digital agriculture and labor: a few challenges for social sustainability. Journal of Sustainability, 13 (11): 5980. http://doi.org/10.3390/su13115980

Prihadyanti, D. Dan S.A. Aziz, 2023. Indonesia toward sustainable agriculture do technology based start ups play a crucial role?. J. of Business Strategy and Development, 6 (2):140-157. https://doi.org/10.1002/bsd2.229

Rolandi, S., G. Brunori, M. Bacco & I. Scotti, 2021. The digitalization of agriculture and rural areas: towards a taxonomy of the impacts. Journal of Sustainability, 13 (9): 5172. https://doi.org/10.3390/su13095172

Rotondi, V., R. Kashyap, L.M. Pesando, S. Spinelli, and F.C. Billari, 2020. Leveraging mobile phones to attain sustainable development". Proceedings of the National Academy of Sciences of the United States of America, 117 (24): 13413-13420. https://doi.org/10.1073/pnas.1909326117.

Sanga, C. A., M. Mussa, S. Tumbo, M.R.S. Mlozi, L. Muhiche, and R. Haug, 2014. On the development of the mobile based agricultural extension system in Tanzania: a technological perspective. International Journal of Computing and ICT Research (IJCIR), 8 (1): 49-67. https://www.ijcir.org/volume8-issue1/article5.pdf.

Saravanan, K. & Saraniya S., 2018. Cloud IoT based novel livestock monitoring and identification system using UID. Sensor Review, 38 (1): 21-33. https://doi.org/10.1108/SR-08-2017-0152.

Sharma, A., A. Sharma, A. Tselykh, A. Bozhenyuk, T. Choudhury, M.A. Alomar & M. Sánchez-Chero, 2023. Artificial intelligence and internet of things oriented sustainable precision farming: towards modern agriculture. Open Life Sciences, 18 (1): 20220713. https://doi.org/10.1515/biol-2022-0713

Sharma, N.R., S. Sharma & D. Sharma, 2020. Towards a mobile app technology-enabled sustainable agriculture in India. Plant Archives, 20 (2): 3065-3071.

Shen, Z., S. Wang, J.P. Boussemart & Y. Hao, 2022. Digital transition and green growth In Chinese agriculture. Technological Forecasting and Social Change, 181: 121742. https://doi.org/10.1016/j.techfore.2022.121742.

Subramanian, A., 2021. Harnessing digital technology to improve agricultural productivity?. Plos One, 16 (6): 0253377. https://doi.org/10.1371/journal.pone.0253377

Tianyu, Q., L. Wang, Y. Zhou, L. Guo, G. Jiang & L. Zhang, 2022. Digital technology-and-services-driven sustainable transformation of agriculture: cases of China and The EU. Journal of Agriculture, 12 (2): 297. https://doi.org/10.3390/agriculture12020297.

Ugochukwu, A. I. & P. W. B. Phillips, 2017. "Technology Adoption by Agricultural Producers: A Review of The Literature, 361-377". In: From Agriscience to Agribusiness. Innovation, Technology, and Knowledge Management (Eds. N. Kalaitzandonakes, E. Carayannis, E. Grigoroudis & S. Rozakis). Springer, Cham. 361-377 pp. https://doi.org/10.1007/978-3- 319-67958-7_17.

Wang, H & Y. Tang, 2023. Spatiotemporal distribution and influencing factors of coupling coordination between digital village and green and high-quality agricultural-development evidence from China. Journal of Sustainability (Switzerland),15 (10): 2-22. https://doi.org/10.3390/su15108079.

Wang, X., D. Cao, C. Jing & A. Daowd, 2020. AI and IoT-based collaborative business ecosystem: a case in chinese fish farming industry. International Journal of Technology Management, 82 (2): 151-171. https://doi.org/10.1504/IJTM.2020.107856.

Washizu, A. & S. Nakano, 2022. Exploring the characteristics of smart agricultural development in Japan: analysis using a smart agricultural kaizen level technology map. Computers and Electronics In Agriculture, Vol.196. https://doi.org/10.1016/j.compag.2022.107001.

Xie, L., B. Luo & W. Zhong, 2021. How are smallholder farmers involved in digital agriculture in developing countries: a case study from China. Land, 10 (3): 245. https://doi.org/10.3390/land10030245.

Xie, Y., Z. Chen, F. Boadu & H. Tang, 2022. How does digital transformation affect agricultural enterprises’ pro-land behavior: the role of environmental protection cognition and cross-border search. Technology In Society, 70: 01991. https://doi.org/10.1016/J.Techsoc.2022.101991.

Zhang, X. & D. Fan, 2023. Can agricultural digital transformation help farmers increase income? an empirical study based on thousands of farmers in Hubei Province. Environment Development and Sustainability, 25 (4): 1-27. https://doi.org/10.1007/s10668-023-03200-5.

Zhong, R, H. Qiang N. & D.Y. Qi, 2022. Digital economy, agricultural technological progress, and agricultural carbon intensity: evidence from China. International Journal of Environmental Research and Public Health, 19 (11): 6488. https://doi.org/10.3390/ijerph19116488

Zhu, M., Y. Li, Z. Khalid & E. Elahi, 2023. Comprehensive evaluation and promotion strategy of agricultural digitalization level. Sustainability, 15 (8): 6528. https://doi.org/10.3390/su15086528.