Transformative Potential of Digital Agriculture for Enhancing Global Food Security

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Abstract. The integration of digital technologies in agriculture has great prospects in solving the problems of global food security in the 21st century. The future lies in big data and the analyses based on it. This paper analyses existing research in order to reveal the impact of digital agriculture on food security. The paper considers technologies such as the Internet of Things (IoT), global positioning system (GPS) and blockchain. These technologies are analysed for their role in optimizing agricultural processes and transforming traditional farming practices. The results of the study reveal the impact of data analytics on data-driven decision making, accurate resource management, and greater transparency across the entire food value chain. Data analytics empowers both large enterprises and SMEs by promoting sustainable practices while adapting to the challenges of climate change. This study also focuses on technology accessibility, data security, knowledge integration, and policy frameworks. Aligning technological solutions with socio-economic, environmental and ethical considerations, digital agriculture becomes a key solution to achieve sustainable and equitable global food security.

1 Introduction

The 21st century has ushered in a new stage of socio-economic challenges and opportunities for global food security. According to the United Nations Sustainable Development Goals, the global population will reach 9.7 billion by 2050. At the same time, urbanization and changing eating habits can lead to an increase in demand for food, so the pressure on agricultural structures increases every year [1]. Since this problem is relevant in many countries, the need to ensure a stable and sufficient food supply comes to the fore. In this context, the emergence of digital agriculture, characterized by the integration of advanced technologies into traditional farming methods, represents an objective solution to achieve sustainable food security [2].

It must be understood that historically, agriculture has undergone numerous developments that have changed the way food is produced, distributed and consumed in society. According to Amirova, the "Green Revolution" of the mid-20th century led to the

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emergence of high-yielding crop varieties and modern agricultural practices, which greatly increased agricultural productivity and prevented widespread famine [3]. Today, in the context of confrontation between various blocks of countries and the looming food crisis, the scale of possible food problems goes beyond a simple increase in productivity [4]. Hence the need for a holistic transformation of agricultural systems to address multifaceted challenges such as resource scarcity, climate change, environmental degradation and socioeconomic inequalities.

From a scientific point of view, digital agriculture is a concept based on the fusion of digital technologies and agriculture. This concept harnesses the power of automation, networking and big data analytics to control and improve every aspect of the agricultural value chain [5]. At its core, digital agriculture aims to optimize the use of resources, improve decision-making and ensure sustainability through the integration of modern digital technologies. These technologies are able to provide completeness of information for making the right decisions, decision support tools, monitoring and control of production processes and supply chains based on data analysis [6].

In the context of modern geo-political problems and possible economic and environmental risks, the importance of achieving food security becomes a key task. Food security, as defined by the United Nations, exists when the entire population, at all times, has physical, social and economic access to sufficient, safe and wholesome food that meets their needs and preferences for an active and healthy life [7]. Food security encompasses not only the quantitative aspect of producing enough food to meet demand, but also the qualitative aspect of ensuring access to nutritious and culturally acceptable diets. The implementation of such aspects entails increasing the resilience of agricultural systems to shocks and stresses, both climatic and economic, providing the population with everything necessary for a quality life.

2 Methods

The main methods used in this study refer to the literature review. The literature review includes an analysis of major scientific articles, reports and case studies from various scientific communities. The key values of the analysis were digital technologies and agriculture. The purpose of the analysis was to synthesize scientific solutions from the existing literature. The study assesses the effectiveness of key technologies such as the Internet of Things, GPS and blockchain in streamlining agricultural processes and improving food security.

3 Results

This section of the study reviews the main identified agricultural practices based on technologies such as the Internet of Things, global positioning system, blockchain, decision support systems and big data analysis.

One of the first technological solutions for precision farming is based on the use of a global positioning system in agriculture. This method is known as GPS-guided precision farming. GPS technology has led to a change of concept in the operation of agricultural machinery [8]. With GPS-guided precision farming, farmers have been able to control the application of fertilizers, pesticides and other inputs based on the specific needs of each area of their fields. This technology minimizes overuse, preventing environmental pollution and reducing production costs. The use of GPS-guided precision farming technology facilitates the implementation of site-aware management practices that consider differences in soil types, maximizing yield potential [9]. By minimizing resource wastage and

optimizing yields, GPS-guided precision farming contributes to both economic and environmental sustainability.

Since the introduction of IoT devices in agriculture, the concept of IoT-enabled precision farming has emerged [10]. The integration of IoT devices in agriculture has ushered in a new phase of real-time monitoring and data-driven management. These interconnected devices collect data on various parameters such as temperature, moisture, soil pH and plant health. Big data allows farmers to make informed decisions, anticipate potential problems and take targeted action [11]. For example, wireless sensors strategically placed in fields can continuously monitor soil moisture levels and relay data to farmers, allowing for precise irrigation planning. This solution not only saves water resources, but also prevents over-watering, which can lead to nutrient leaching and soil degradation. Another advantage of these technologies is that IoT devices can monitor weather conditions and pest activity, facilitating timely response and reducing crop losses [12].

Blockchain technology has broken into all sectors of the economy, including agriculture, providing transparency and traceability of all stages of the movement of products from the farmer to the store [13]. Blockchain technology holds great promise in bringing transparency and traceability to agricultural supply chains, thereby enhancing certain aspects of food security. With growing concerns about fraud, contamination, and food labelling, blockchain offers a decentralized and tamper-proof record of transactions and data. This approach ensures that consumers can trace their food from farm to store, ensuring it is authentic and safe. Blockchain-based smart contracts can facilitate transactions between stakeholders, reducing the number of intermediaries and increasing efficiency [14]. This increased transparency not only builds consumer confidence, but also enhances accountability in the supply chain, ensuring that food reaches its destination without interruption.

Another important technology in this study is the decision support system. The integration of digital technologies in agriculture is transforming farmers from mere producers into data-driven decision makers [15]. Having real-time data on crop status, weather conditions, market trends and resource use allows farmers to proactively address challenges and maximize opportunities [16]. This leads to more informed choices in terms of crop selection, planting schedules, pest and disease management, and resource allocation. Using data, farmers can optimize their methods to increase productivity and minimize negative environmental impacts [17]. This democratization of data-driven analysis levels the playing field, benefiting small and large farmers alike.

An important factor in the interaction of digital technologies and agriculture is increased stability and adaptability. The focus of digital agriculture on real-time data collection and monitoring provides farmers with the tools to instantly adapt to changing environmental conditions. As climate change continues to bring unpredictability to agriculture, it follows that the ability to monitor factors such as temperature, rainfall and soil moisture in real time is becoming a major advantage [18]. Farmers can quickly adjust their strategies to respond to climate fluctuations and reduce potential losses. Information gained from cyclical time data can help identify long-term trends, helping farmers make informed decisions about crop choices and management practices that are best suited to changing local conditions.

Summing up this section, it should be confirmed that the integration of digital technologies in agriculture is an important moment in the evolutionary path of agricultural development and has a significant effect on the path of global food security. Our findings highlight the multifaceted benefits of digital agriculture, from precise resource management via the Internet of Things and GPS, to transparent supply chains using blockchain, to data-driven decision making. These technological advances have the potential to change traditional ways of producing, distributing and consuming food. These methods allow us to face the challenges of the 21st century while maintaining resilience and ingenuity.

4 Discussion

The results presented in this study underscore the transformative impact of digital technologies on modern agriculture. This discussion section will delve into the significance, importance, and relevance of these findings, emphasizing their implications for agricultural practices, sustainability, and global food security. Discussion will be based on the following 6 aspects of digitalization of agriculture:

4.1 Precision Farming Through GPS Technology

The introduction of GPS-guided precision farming represents a fundamental shift in agricultural operations. By enabling farmers to tailor their actions to the specific needs of each field, this technology minimizes overuse of resources like fertilizers and pesticides. As a result, it not only prevents environmental pollution but also reduces production costs, making agriculture more sustainable both economically and environmentally. The implementation of site-aware management practices driven by GPS technology maximizes yield potential, emphasizing its potential to boost food production in a world with a growing population and finite resources.

4.2 IoT-Enabled Precision Farming

IoT devices have ushered in a new era of real-time monitoring and data-driven management in agriculture. These interconnected sensors provide continuous data on critical parameters such as soil moisture, temperature, and plant health. The utilization of big data analytics allows farmers to make informed decisions, anticipate issues, and take targeted actions. IoT-enabled precision farming reduces water consumption through precise irrigation planning, mitigates crop losses by monitoring weather conditions and pest activity, and enhances overall resource efficiency.

4.3 Blockchain for Transparency and Traceability

Blockchain technology's impact on agriculture is remarkable, particularly in enhancing transparency and traceability within the supply chain. It addresses concerns related to fraud, contamination, and food labelling by providing a tamper-proof record of transactions and data. This transparency not only builds consumer trust but also streamlines supply chain operations through smart contracts, reducing intermediaries and increasing efficiency. Ultimately, blockchain ensures the authenticity and safety of food products, contributing to food security.

4.4 Data-Driven Decision Making

The integration of decision support systems empowers farmers to become data-driven decision-makers. Real-time data on crop status, weather conditions, market trends, and resource utilization allows farmers to proactively address challenges and seize opportunities. This democratization of data-driven analysis benefits farmers of all scales and promotes more sustainable agricultural practices.

4.5 Adaptability and Resilience

Digital agriculture's focus on real-time data collection and monitoring equips farmers with the tools to adapt swiftly to changing environmental conditions. This is particularly crucial in an era marked by climate change-induced unpredictability. The ability to monitor factors like temperature, rainfall, and soil moisture in real time empowers farmers to adjust strategies, reduce potential losses, and make informed decisions about crop selection and management practices suited to changing local conditions.

4.6 Implications for Global Food Security

In summary, the integration of digital technologies into agriculture represents a pivotal moment in the evolution of agricultural development. The multifaceted benefits outlined in this study, from precise resource management facilitated by IoT and GPS to transparent supply chains using blockchain and data-driven decision-making, collectively contribute to increased food security on a global scale. These technological advancements have the potential to revolutionize traditional methods of food production, distribution, and consumption. They provide us with the tools to tackle the challenges of the 21st century while fostering resilience and innovation in agriculture.

5 Conclusion

This study underscores the paramount importance of embracing digital technologies in agriculture to ensure a sustainable and secure food supply for future generations. It is imperative for stakeholders across the agricultural sector, including farmers, policymakers, and technology providers, to recognize the value of these innovations and work together to harness their full potential. By doing so, we can navigate the complexities of a changing world while safeguarding our ability to feed the growing global population.

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