Proceedings of the 8th International Conference on Economic Management and Green Development
DOI: 10.54254/2754-1169/121/20242631

Digitizing Agriculture: Strategic Insights into Traditional Challenges and Modern Management Solutions

Jiahang Wu[1,a,*]

[1]*School of Mathematics, University of Birmingham, Edgbaston, Birmingham, United Kingdom*
a. JXW1474@student.bham.ac.uk
**corresponding author*

Abstract: This study systematically analyzes key factors influencing the digitization of agriculture and offers practical management recommendations. Through an in-depth examination of traditional agricultural issues, it identifies significant challenges such as low production efficiency, improper resource utilization, insufficient environmental monitoring capabilities, and a lack of financial and technical support. The digitization of agriculture significantly enhances production efficiency by integrating advanced technologies like the Internet of Things (IoT), remote sensing, big data, and artificial intelligence. The expansion of these technologies can effectively increase crop yields, reduce resource waste, and strengthen farmers' adaptive capabilities. Looking ahead, digital management in agriculture should further promote the integration of different data sources for more comprehensive decision-making. Additionally, the development of intelligent systems with self-learning capabilities is essential for improving the accuracy and efficiency of decision-making processes. Research on and promotion of eco-friendly agricultural technologies to steer agriculture toward sustainable and green development should also be a priority for future initiatives.

Keywords: Digital Agriculture, Precision Farming, Agricultural Automation.

1. Introduction

Digitization of agriculture involves the development and use of advanced digital technologies and tools such as the Internet of Things (IoT), big data, remote sensing technology, artificial intelligence (AI) to optimize all aspects of agricultural production [1, 2]. This transformation aims to increase production efficiency, reduce operational costs, and improve resource utilization, bringing new development opportunities to agriculture. The factors influencing the process of agricultural digitization are numerous and complex, encompassing technological, economic, policy, social, and environmental aspects. Therefore, an in-depth study of these influencing factors is crucial for advancing the digitization of agriculture [3].

Under the traditional agricultural model, the production process relies on experience and labor, resulting in low resource utilization efficiency and insufficient environmental protection measures. These issues hinder the sustainable development of agriculture [4]. To advance agricultural digitization, it is essential to address these traditional problems and face the challenges brought by new technologies. For example, technological challenges include the operation of hardware equipment and data standardization issues; economic challenges involve high initial investments and

DOI: 10.54254/2754-1169/121/20242631

ongoing maintenance costs; policy challenges related to the level of government support and regulatory policies that directly impact the promotion of agricultural digitization; and social challenges concern farmers' acceptance of new technologies and their proficiency in using them, both of which are crucial for digital transformation.

This study aims to systematically analyze the key factors affecting the digitization of agriculture and explore their practical applications in agricultural production. The research proposes feasible management recommendations by identifying the potential obstacles and opportunities encountered in agricultural digitization. These recommendations will provide valuable references for agricultural enterprises and policymakers, thereby promoting the digital transformation and sustainable development of agriculture.

2. Analysis of Traditional Agricultural Problems

Traditional agricultural production relies on manual labor and experience, and this model reveals many areas for improvement in the modernization process. One of the most significant issues of traditional agriculture is low production efficiency. Each stage of agricultural production, such as planting, irrigation, fertilization, and harvesting, requires substantial manual input and repeated trials. This method could be more efficient and susceptible to individual experience and operational skill variations, leading to unstable crop yields and quality. Studies indicate that automation and mechanization in agriculture can significantly improve labor productivity. According to Jiquan Peng's research, agricultural mechanization can notably enhance production efficiency and yield [5]. Mechanized equipment, such as mechanical seeding and deep fertilization technology, greatly increases production efficiency by reducing seed wastage and optimizing fertilizer use. These technologies decrease the need for manual labor while improving crop yield and quality.

The resource utilization efficiency in traditional agriculture is low, particularly in water, fertilizers, and land use. Due to the lack of precise data and modern technologies, farmers often rely on experience for resource allocation, leading to issues such as excessive use of fertilizers, water wastage, and soil degradation. For instance, traditional irrigation methods may result in water resource wastage, whereas precision agriculture technologies can significantly reduce water consumption. According to David Cleary's research, precision agriculture technologies can reduce water and fertilizer usage by 20% to 40% without negatively impacting crop yields; in some cases, it can even enhance yields. Specifically, precision irrigation technology can accurately deliver the right amount of water at the right place and time, reducing water resource wastage [6].

Traditional agriculture needs the capability for real-time environmental monitoring, making it difficult to respond promptly to natural disasters or environmental changes. This needs to be improved in monitoring so that farmers can take effective measures when faced with sudden climatic events or pest outbreaks, potentially resulting in severe economic losses. By contrast, applying digital agriculture technologies in environmental monitoring demonstrates that real-time monitoring and early warning systems can significantly reduce disaster risks. For example, in 2010, Pakistan experienced severe flooding. The lack of effective environmental monitoring and warning systems led to inadequate disaster response, causing substantial losses in the agricultural sector. Over 20% of farmland was submerged, resulting in 1,985 deaths and 2,946 injuries.

The lack of funding and technical support further restricts the application of modern equipment and technologies in traditional agriculture. Due to financial constraints, many farmers need help to afford the initial investment in advanced agricultural equipment and technologies. The lack of technical training and support makes it difficult for them to master and utilize new agricultural technologies. This predicament is particularly evident in developing countries, leading to delays in the agricultural modernization process. For instance, a report highlights that farmers, due to insufficient funds, cannot invest in advanced agricultural technologies and equipment, such as solar

DOI: 10.54254/2754-1169/121/20242631

pumps and automated irrigation systems, thus limiting improvements in agricultural production efficiency.

Traditional agriculture faces numerous issues in production efficiency, resource utilization, environmental monitoring, informatization, and funding and technical support. These problems not only limit the efficiency and effectiveness of agricultural production but also have negative impacts on the environment [7]. A systematic analysis of these issues can provide clear directions and practical recommendations for advancing agricultural digitization.

3. Implementation and Management Strategies for Agricultural Digitization

Agricultural digitization revolutionizes traditional farming methods by integrating multiple advanced technologies, providing farmers with more efficient, precise, and intelligent management tools. This section will explore the main technologies used in agricultural digitization and their application strategies.

The application of the IoT in agricultural digitization is particularly widespread. IoT technology involves deploying sensors to collect real-time data on soil health, crop growth, and weather patterns. These sensors can monitor key indicators such as soil moisture, temperature, and nutrient content, providing farmers with immediate field data. For example, soil sensors can detect soil moisture levels, helping farmers optimize irrigation timing and amounts to prevent water waste and excessive soil dryness. In Spain, IoT technology is used in smart irrigation systems, assisting farmers in optimizing irrigation schedules and quantities based on real-time soil moisture data. These systems use wireless sensor networks to monitor soil conditions and provide instant feedback, reducing water usage and improving water resource efficiency.

The application of remote sensing technology and drones in agriculture has significantly enhanced the precision and efficiency of agricultural management. Using high-resolution images captured by drones, farmers can obtain extensive information about their fields from the air, such as crop health status, pest distribution, and soil quality. Drone remote sensing technology offers flexibility, high resolution, and rapid response capability, enabling the swift acquisition of data over large areas. For instance, drones can fly at low altitudes, capturing real-time images of fields at a resolution of 0.01 meters to 0.1 meters, far surpassing the capabilities of traditional satellite remote sensing. This high-precision data supports precision agriculture management, helping farmers optimize irrigation and fertilization strategies and respond promptly to pest and disease issues. Drones are particularly effective in crop health monitoring, soil analysis, and environmental monitoring. Through multispectral and hyperspectral imaging, drones can monitor crop growth conditions in detail and identify areas affected by pests and nutrient deficiencies. For example, analyzing drone imagery can accurately reflect the moisture content of crops, supporting appropriate irrigation. Additionally, equipped with LiDAR and thermal imaging devices, drones can provide information on soil moisture and texture, optimizing field management. In environmental monitoring, drones can comprehensively monitor changes in the agricultural environment, providing real-time information on water resource management and pollution spread [8].

The application of AI in agriculture has significantly enhanced the efficiency and accuracy of agricultural management. AI technology processes data from sensor devices to generate dynamic predictive models, optimizing planting, irrigation, and fertilization strategies. AI analyzes soil using artificial neural networks (ANN) and employs fuzzy neural network classifiers for unsupervised clustering and classification studies. These technologies assist farmers in selecting appropriate crop varieties and fertilization strategies, improving land use efficiency. They can also forecast irrigation water demand and daily river runoff through machine learning models such as Bayesian Neural Networks (BNN), Support Vector Regression (SVR), and Gaussian Processes (GP). These models help farmers make irrigation decisions and optimize water resource management. For example, the

DOI: 10.54254/2754-1169/121/20242631

study by Elgaali et al. developed a feed-forward ANN model to analyze the supply and demand of irrigation water [9].

The application of automated equipment and robots in agricultural production has become increasingly widespread, significantly enhancing production efficiency and reducing labor costs. For instance, automated planters can perform precise seeding operations using autonomous navigation and path planning technologies, ensuring uniform seed distribution and optimal planting depth. This precise planting technology improves operational efficiency and accuracy while reducing manual intervention. In the weeding stage, robotic weeders utilize machine vision and target recognition technologies to automatically identify and remove weeds, reducing reliance on chemical herbicides. These technologies use GPS to map weed distribution and spray herbicides precisely based on weed density, controlling herbicide usage and minimizing environmental pollution. For harvesting, picking robots equipped with vision sensors and mechanical arms can automatically determine crop ripeness and perform accurate harvesting. For example, tomato-picking robots combine sensor technologies and mechanical arm designs to increase picking speed and accuracy, reducing manual labor. The application of these automated technologies not only optimizes agricultural operations but also advances agriculture towards greater intelligence and precision [10].

Agricultural digitization's implementation and management strategies rely on the collaborative application of various advanced technologies. These technologies enhance the precision and efficiency of agricultural production and provide farmers with scientific decision-making support. Through case studies and technical validation, it is evident that agricultural digitization is bringing profound changes to modern agriculture and guiding future agricultural development.

4. Recommendations for Agricultural Digitization Management

Digital agriculture management requires an integrated framework covering all aspects of data collection, analysis, management, and decision support. Establish a comprehensive management platform to achieve continuous collection and analysis of farmland data through the Internet of Things, remote sensing technology and big data analysis. The platform should have crop monitoring, resource management, and disaster early warning functions to provide farmers with all-round agricultural management support. In addition, agricultural data standards need to be developed to make data accurate and consistent, promote the sharing and exchange of agricultural data, and make efficient use of resources. The achievement of data standardization requires the active promotion of the government and industry associations and the formulation of relevant policy measures.

The digital management of agriculture requires an integrated management framework covering data collection. In the digital management of agriculture, the promotion of precision agriculture technology is important. Wuhan HeDa Technology has achieved remarkable results in this part. Through IoT technology and big data analysis, HeDa Technology has developed an intelligent irrigation system that effectively reduces water waste and improves water use efficiency. In addition, their drone remote sensing technology in crop health monitoring can effectively identify areas of pests, diseases and nutritional deficiencies, improving monitoring accuracy and reducing losses. HeTech also uses AI technology for soil analysis, irrigation prediction, and machine learning models to optimize agricultural production, significantly improving productivity and resource utilization.

Continuous improvement in the digital management of agriculture requires continuous updating of technology and upgrading of farmers' skill levels. New technologies should be introduced continuously, and farmers' professional skills should be improved through systematic training to keep them abreast of the latest agricultural technologies. In addition, the government should formulate incentive policies to support the research, development and dissemination of agricultural digitization technologies, increase funding for agricultural digitization projects, and provide loans and subsidies to help farmers purchase equipment.

DOI: 10.54254/2754-1169/121/20242631

5. Conclusion

This study systematically analyses the key factors influencing the digitization of agriculture and proposes practical management recommendations. Through an in-depth analysis of traditional agricultural problems, low production efficiency, inappropriate resource utilization, insufficient environmental monitoring capacity and lack of financial and technical support are pointed out. Through the cooperation of the Internet of Things, remote sensing technology, big data, artificial intelligence and other technologies, agricultural digitalization has greatly improved production efficiency. Extension of these technologies can effectively increase crop yields, reduce resource wastage and enhance the coping capacity of farmers.

In the future, the digital management of agriculture should further promote data fusion and intelligent decision-making systems. Research is needed on integrating different data sources to provide more comprehensive decision-making. At the same time, intelligent systems with self-learning capabilities should be developed to improve the accuracy and efficiency of decision-making. In addition, research on and promotion of environmentally friendly agricultural technologies to promote the development of agriculture in a sustainable and green direction should also be an important direction for the future.

References

[1] Abbasi, R., Martinez, P., & Ahmad, R. (2022). The digitization of agricultural industry–a systematic literature review on agriculture 4.0. Smart Agricultural Technology, 2, 100042.

[2] Stupina, A. A., Rozhkova, A. V., Olentsova, J. A., & Rozhkov, S. E. (2021, September). Digital technologies as a tool for improving the efficiency of the agricultural sector. In IOP Conference Series: Earth and Environmental Science, 839(2) 02209. IOP Publishing.

[3] Wolfert, S., Ge, L., Verdouw, C., & Bogaardt, M. J. (2017). Big data in smart farming—a review, agricultural systems. 153: 69–80.

[4] Qu, Y., Lyu, X., Peng, W., & Xin, Z. (2021). How to evaluate the green utilization efficiency of cultivated land in a farming household? A case study of Shandong Province, China. Land, 10(8), 789.

[5] Peng, J., Zhao, Z., & Liu, D. (2022). Impact of agricultural mechanization on agricultural production, income, and mechanism: evidence from Hubei province, China. Frontiers in Environmental Science, 10, 838686.

[6] Cleary, D. (2017). Precision Agriculture: Potential and Limits. The Nature Conservancy. Retrieved from https://www.nature.org/en-us/what-we-do/our-insights/perspectives/precision-agriculture-potential-and-limits/

[7] Altieri, M. A. (2002). Agroecology: the science of natural resource management for poor farmers in marginal environments. Agriculture, ecosystems & environment, 93(1-3), 1-24.

[8] Li, Y., et al. (2015). Development and application of UAV remote sensing technology in agriculture. Anhui Agricultural Sciences, 43(25), 3.

[9] Liu, X., Zheng, H., & Shi, N., et al. (2013). Advances in the application of artificial intelligence in agricultural production. Journal of Fujian Agriculture, 28(6), 6.

[10] Zhao, X. (2010). Main applications of intelligent robots in the field of agricultural automation. Chinese Agricultural Science Bulletin, 26(10), 5.