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Opportunities And Challenges of Digital Supply Chains in the Agriculture Industry

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Abstract. This research analyzes the opportunities and challenges in the digitalization of Indonesia's agricultural supply chain system, focusing on the role of key technologies such as *the Internet of Things (IoT), big data*, Artificial Intelligence *(AI),* and *blockchain*. Indonesia's agricultural sector, which is strategic for food security, is still hampered by traditional supply chain practices characterized by limited access to information, low distribution efficiency, and lack of transparency. Various literature studies underscore the potential of digital technologies, including the concepts *of smart farming* and precision agriculture, in improving production accuracy, reducing operational costs, and strengthening farmers' competitiveness. Specifically, *blockchain* offers solutions to improve product traceability and build consumer trust. This study uses a descriptive qualitative approach through a literature review of national and international journals published between 2021 and 2025. The analysis is carried out by identifying the opportunities, challenges, and strategic implications of digitalization. The results of the study found that the key opportunities of digitalization include improving production efficiency, logistics optimization, AI-based demand prediction, and transaction transparency. However, digitalization also faces major challenges such as limited digital infrastructure, low technological literacy among farmers, high initial investment costs, and data security and standardization issues. The results of the study emphasized that the digitalization of the supply chain has significant potential to strengthen food security and improve the welfare of farmers. The successful implementation of digitalization is highly dependent on regulatory support, digital capacity building of agricultural actors, and cross-stakeholder collaboration to create an inclusive and sustainable digital agriculture ecosystem.
Keywords: Digital Supply Chain, Agriculture, Opportunities, Challenges, Digital Transformation

INTRODUCTION

The agricultural industry is a strategic sector that supports food security and plays an important role in the global economy and improves people's welfare. However, the structure of the agricultural supply chain in various countries, including Indonesia, is still grappling with fundamental problems that hinder the effectiveness and competitiveness of this sector. Limited access to information, price volatility, and inequality in the distribution of value between supply chain actors are recurring problems. According to BPS, although the national internet penetration rate has reached 66.48% in 2022, the use of digital technology among farmers is still limited. The

agricultural sector, especially the horticulture sector, faces serious problems at the post-harvest distribution and handling stage, namely the level of food loss in vegetable and fruit commodities caused by inadequate distribution systems and storage facilities. The combination of limited access to information and technology and high post-harvest losses confirms that Indonesia's agricultural supply chain is still facing fundamental problems that reduce the efficiency and competitiveness of the sector as a whole. This situation confirms that conventional supply chain mechanisms are not yet able to keep up with market changes that are increasingly rapid and competitive.

Traditional agricultural supply chains are generally characterized by many actors working separately, weak institutional coordination, and low transparency of information flow. Farmers often do not have actual market information about demand, product quality, and distribution patterns, so production decisions are less than optimal. Meanwhile, distributors and downstream industry players face difficulties in maintaining quality standards, ensuring product traceability, and maintaining supply continuity. This condition also increases the potential for *food loss and waste*, which has implications for economic inefficiency and increased food insecurity. Advances in digital technology in the Industry 4.0 era provide new opportunities to overcome these various obstacles. Various innovations ranging from the Internet of Things (IoT), big data analytics, artificial intelligence, blockchain, to digital commerce platforms encourage the formation of a more transparent, adaptive, and sustainable supply chain. A number of international studies prove that the use of digital technology in the agricultural sector is able to drive real efficiency. Studies on smart farming, for example, show that digitalization helps improve operational performance and productivity in a sustainable manner (Rasyid & Ningsih, 2024). Empirical findings on the agrifood supply chain also show similar results, namely the use of digital technology can increase supply chain efficiency by up to 50.9%, reduce logistics costs by 28%, reduce product damage by 41.6%, and speed up the delivery process by around 25% (Dong, et.al, 2023). Precision agriculture research also confirms that digital technology with a precision irrigation system is able to produce water savings of at least 20% and is able to increase production (Mgendi, 2024). Overall, these findings show that digitalization not only reduces costs and improves distribution flows, but also significantly increases the competitiveness of agricultural products.

Although it provides great potential, the implementation of digital supply chains in the agricultural sector also faces a number of obstacles. Uneven access to digital infrastructure in rural areas is the main obstacle. Low technology literacy among farmers, especially small farmers, also hinders the optimal use of technology. In addition, the need for large investments, resistance to change, and the problem of system integration between digital platforms are challenges in itself. Data security and privacy protection issues are also becoming increasingly important as the use of production, distribution, and transaction data in digital systems increases. Various previous studies have examined the role of digital technology in the agricultural sector, but most of them are still focused on technical aspects, such as the application of IoT in cultivation or the use of blockchain for product tracking. There have not been many studies that have thoroughly discussed the opportunities and challenges of digitalization in all supply chain flows, starting from the production process, distribution, to marketing. In addition, there is a lack of research that explores the readiness of agricultural ecosystems to face digital transformation and its implications for the sector's development policies.

Finally, taking these conditions into account, the literature review on "Opportunities and Challenges of Digital Supply Chains in the Agricultural Industry" has become increasingly relevant. This literature review aims to identify the benefits that can be generated from supply chain digitalization while analyzing the barriers that arise in its implementation. This literature review is expected to provide comprehensive information for the preparation of digital-based agricultural development strategies, both for the government, agribusiness actors, and other stakeholders involved in accelerating the transformation of the agricultural system.

LITERATURE REVIEW

Supply chain management is a strategic approach that emphasizes the importance of active coordination and comprehensive integration between demand management, supply processes, distribution, information exchange, and relationships between actors in the supply chain system (Aisyah et.al., 2025). The supply chain is an important component in production management because it is related to the progress of control and planning in a production system. Not only from the production side, the sustainability of supply chain management can be integrated along the supply chain. One of the sectors that involves sustainable supply chain management is the agricultural sector. Economic dynamics make developing countries heavily dependent on agricultural production and global resilience with a percentage of 11% of the world's land occupied by the agricultural sector (Nurmalina, et.al., 2024). In the agricultural sector, various concepts have emerged that describe various forms of digitalization in the agricultural production system, value chain, and the broader food system, including smart agriculture or *Smart Farming*. This concept emphasizes the use of information and communication technology in cyber-based and physical agricultural management. In its development, IoT and *Cloud Computing* opens up opportunities to utilize robots and artificial intelligence in agriculture. In addition, precision agriculture has also emerged, which is a concept that approaches systemic agriculture with the aim of reducing inputs, increasing efficiency, and achieving sustainability of agriculture. This concept provides opportunities to regenerate the natural environment, manage farming using digital technology, and significantly increase efficiency. Meanwhile, *Agriculture Decision* is an engineering approach in agriculture that aims to optimize the use of agricultural resources. This approach is known for the principle of using only adequate amounts of inputs. This includes the application of nutrients, seeds, water, and other agricultural resources in sufficient and needed quantities. A broader concept is Digital agriculture which can be explained as the application of a system *Big Data* and precision technologies in agriculture, combining various practices that collectively reflect the transformation of food farming systems. This whole concept is recognized as part of Agriculture 4.0 (*Agriculture* 4.0) which is the adoption of agricultural digitalization by combining *Big Data* and IoT (Azis & Suryana, 2023).

Digital developments have occurred in the field of agriculture and the food supply chain, so the terms "Agriculture 4.0" and "Agri-Food" have emerged. Agriculture 4.0 refers to a new generation of digital agriculture. By abandoning traditional methods, increased production and agricultural efficiency can be achieved, costs can be reduced as much as possible, and environmental sensitivity can be guaranteed thanks to artificial intelligence and sensors, etc. Agri-food 4.0 ensures that the process of delivering products from the field to the hands of consumers is transparent and traceable, especially by using blockchain technology (Aslan, 2022). Artificial Intelligence (AI) has become one of the most impactful technologies in the digital transformation of supply chains. AI refers to the ability of machines to mimic and apply human intelligence, such as learning, pattern recognition, decision-making, and problem-solving, to process large and complex data. In the context of supply chains, AI can be used to improve efficiency, accuracy, and flexibility in various aspects, from demand planning to shipping and logistics management. AI technology enables companies to make faster and smarter decisions, reduce costs, and improve customer satisfaction (Manap et.al., 2025).

The benefits of AI can be applied to various fields in the modern agricultural sector. The main benefits of AI include Agricultural Production Management, where AI transforms the food supply chain that includes production, distribution, and consumption. The researchers used AI technology to provide information and guidance on crop rotation planning, planting seasons, water and nutrient management, pest control, disease control. In addition, AI plays a vital role in the function of Disease Monitoring and Disease Diagnosis. AI is also very valuable in providing Scientific Data. With the help of AI, farmers can analyze various software in real time regarding information on weather conditions, temperature, water use or soil conditions on their farmland, making it easier to make more informed decisions (Lukas, et.al., 2025).

Artificial Intelligence (AI) in the agricultural sector functions to increase the efficiency and productivity of agricultural products. The application of AI is able to improve the management of resources, such as water and fertilizers, and support better data-driven decision-making. Technologies such as intelligent irrigation systems and the use of drones have proven effective in reducing resource wastage and increasing crop yields. AI's ability to quickly detect crop diseases

provides an opportunity for farmers to take early precautions and reduce crop losses. Meanwhile, challenges that need to be overcome include unequal access to technology and supporting infrastructure (Amelia, et.al., 2025).

RESEARCH METHODS

This research aims to thoroughly unpack and identify the great potential and real challenges underlying the adoption of digital supply chains in the agricultural sector. To achieve an in-depth understanding, this study uses a descriptive qualitative approach with a literature review method. This approach was chosen because it is able to describe the phenomenon of digital transformation in depth based on the results of relevant previous research, without conducting statistical hypothesis testing. Data sources are obtained from national and international scientific journals, proceedings, research reports, and official government publications related to the digitization of agricultural supply chains, artificial intelligence (AI), Internet of Things (IoT), big data, and blockchain. The literature search process was carried out through the Google Scholar and Scopus databases with a publication year range of 2021–2025. The keywords used include digital supply chain, digital agriculture, *artificial intelligence*, *agricultural blockchain* , opportunities and challenges, and digital transformation.

The stages of the research include: (1) identification and collection of relevant articles based on keywords and criteria, (2) selection of article quality based on topic suitability, journal reputation, and completeness of data, (3) grouping of data based on types of technology, opportunities, and challenges, (4) analysis and synthesis of research results to formulate conclusions and strategic implications. The data analysis technique was carried out qualitatively to identify the main patterns related to benefits, barriers, and the role of digitalization in improving the efficiency and welfare of farmers. With this stage, the research is expected to be able to achieve the goal of comprehensively examining the potential and obstacles of digitalization of the agricultural supply chain.

RESULTS AND DISCUSSION

This research is based on the results of previous research that is relevant to the topic to be discussed. References from previous research were used as material for discussion and data analysis. The following table provides a summary of these references:

Table 1. Summary of Activities Resulted from Researchers on AI for Agriculture.

No	Article	Types of AI	Challenge	Chance
1	Maharani, M. R. D., Hifziah, H., Rahadiarta, I. Komang P. S., Muflikh, Y. N. (2025).,https://doi.org/10.29244/fagb.15.2.227-242	AI (Machine learning (ML) and deep learning technology with a combination of supporting technologies such as blockchain, digital twins, and IoT	The use of machine learning, deep learning, and supporting technologies such as IoT or blockchain is still constrained by data quality, infrastructure limitations, and a lack of skilled human resources	AI significantly improves Post-Harvest Quality, optimally predicts lead times, and manages Demand/Inventory. To ensure Food Safety and Traceability, AI is integrated with blockchain to create a secure and non-manipulable digital footprint across the supply chain, from farmers to end consumers

2	Sugiardi, S. (2025).	Use of Blockchain Technology	Uneven technological infrastructure, low digital literacy among farmers, as well as fairly high initial investment costs and the need for data standardization and collaboration between stakeholders.	Blockchain drives transparency, increases trust, speeds up transactions, and even strengthens smallholder bargaining positions through a secure and verifiable transaction history.
3	Abiri, et.al. (2023). https://doi.org/10.1016/j.heliyon.2023.e22601	Digital agriculture (DA) such as artificial intelligence, automation and robotics, sensors, Internet of Things (IoT)	Digital agriculture technology is still expensive and difficult to operate, especially in areas with limited internet access	Digital agriculture technology is able to reduce waste, predict crop conditions in real-time, and help farmers make more informed and efficient decisions
4	Heryaninda, A. A., Ramadhan, W., Putri, A. K., Sabila, S. A., Arifiani, W., & Budiawati, Y. (2025).	AI in agricultural e-commerce transformation	Uneven digital infrastructure, high technology costs, data security concerns and poor digital literacy among farmers	AI can optimize supply chains, support marketing decision-making, improve operational efficiency and strengthen the competitiveness of agricultural products in the global market
5	Viani, A., Prabawani, B., & Dewi, R. S. (2022). https://ejournal3.undip.ac.id/index.php/jiab	GSCM (Green Supply Chain Managemen)	Lack of understanding related to GSCM, large costs and long implementation time	GSCM has the potential to improve resource use efficiency and improve soil quality in the long term
6	Waluyo, T. (2023). http://ejournal.seaninstitute.or.id/index.php/InfoSains	Internet of Things (IoT)	High device costs, unstable internet, and data security risks	IoT sensors can monitor plant and logistics conditions in real-time, improving supply chain efficiency and transparency
7	Deepthi, A., Hirlekar, V., Kanade, A., Asha, Sengupta, S., Priya, Neeraja, P., & Sriram. (2025).	AI and Blockchain	Inconsistent data, high costs, low technology literacy, data privacy and security issues	AI and Blockchain help automate quality checking, increase transparency of product origin, and strengthen consumer trust
8	*Wihartiko, F. D., Nurdiati, S., Buono, A., & Santosa, E. (2021). https://doi.org/1*	Blockchain for AI & AI for Blockchain	a. The use of blockchain systems by all stakeholders involved in the agricultural supply chain. b. Improved business process system	AI can predict crop yields and commodity prices, as well as help determine planting and distribution times so that agricultural performance becomes more optimal

	0.25126/jtiik.202184059		c. Increasing the role of the government and trust between stakeholders.	
9	Harahap, L. M., Surbakti, O. M. B., Gerald, J., & Ramadhan, R. (2024). https://malaqbippublisher.com/index.php/JIMBE	Technologies such as precision agriculture, Internet of Things (IoT), big data, and artificial intelligence (AI)	a. Limitations of technology infrastructure in rural areas b. Low level of digital literacy among farmers c. The need for large investments in the adoption of new technologies	Technology opens up wider market access, more efficient production, wide market access, government policy support, and the emergence of digital agricultural service innovations
10	Anggraini, F., Putri, A. I., Agustin, A., Neriana, & Sari, R. (2025).	Discuss the advantages and challenges of using Supply Chain	a. Performance metrics that still don't meet expectations b. Information distortion c. Setup imbalance d. Infrastructure constraints	a. Improve operational efficiency b. Increase the competitiveness of the company
11	Danu, M., Mawasandi, F., Nur Aziz, Z., Fahrul Ghifari Rosyadi, M., & Wahyudi, B. (2025).	Internet of Things (IoT)-Artificial Intelligence (AI)-Sensors-Connectivity	a. Data security b. High investment costs c. Infrastructure and regulatory limitations	IoT can improve data visibility, support fast logistics, reduce waste, and strengthen product traceability through real-time sensors.
12	Baladraf, T. T. (2024). https://doi.org/10.24198/jt.vol18n1.4	Digital twin	a. Requires the latest and high-performance software and hardware infrastructure b. High investment and product consumption costs (fairly high cost of procurement of digital twins) c. Lack of expert availability	Digital twins are a potential technology because they cause a multiplier effect by creating integrated agricultural management starting from pre-harvest, harvest, and post-harvest.
13	Miller, T., Mikiciuk, G., Durlik, I., Mikiciuk, M., Łobodzińska, A., & Śnieg, M. (2025). https://doi.org/10.3390/s25123583	Integration of IoT and AI systems (Smart sensing systems and machine learning)	The digital divide and high cost of censorship and lack of attention to ethics and cybersecurity.	The integration of IoT and AI systems enables real-time monitoring, early disease detection, and precision irrigation and fertilization.

14	Rulinawaty, Samboteng, L., Andriyansah, & Alwi. (2023). https://doi.org/10.38035/rrj.v5i4	AI and Blockchain	a. Lack of Data Standardization b. Limitations of Digital Infrastructure in Certain Regions c. Resistance to the Adoption of New Technologies d. Lack of coordination between stakeholders, so an integrated coordination system is needed	a. Improving national food security through improving prediction accuracy and optimizing supply chain networks. b. AI and Blockchain contribute to the development of data-driven food policies
15	Keefe, D. H. S., Jang, H., & Sur, J. M. (2024). https://doi.org/10.1016/j.ajsl.2024.09.001	IoT, Big Data, Blockchain, Digital Platforms (digital agriculture)	a. Limited digital infrastructure b. Low digital literacy c. Low awareness of the benefits of digitalization d. Lack of stakeholder collaboration e. Data security f. The threat of climate change	a. Increasing farmers' income b. Cost and operational efficiency c. Access to information and education d. Cross-sector collaboration e. Reduce waste f. Stronger & more responsive supply chain

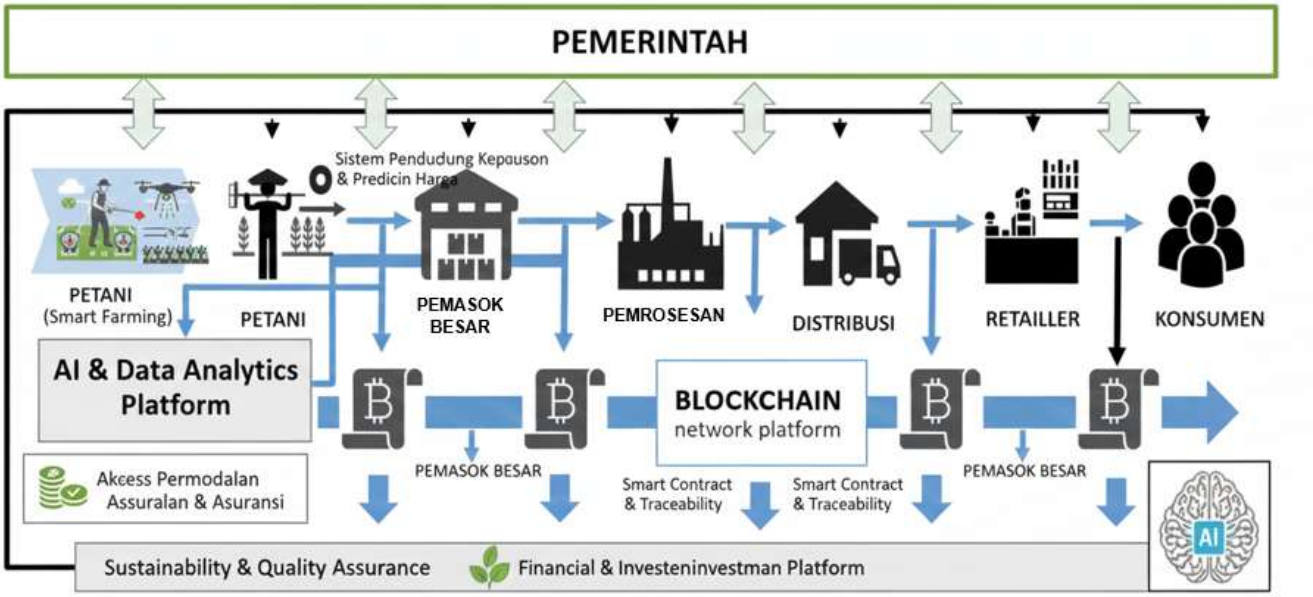
Based on the Table above, it can be seen that all the articles collected discuss the use of artificial intelligence (AI) in the agricultural sector, especially in land management, pest detection, weather prediction, and harvest optimization. In general, the data shows that AI is now one of the important elements in agricultural modernization. AI is seen as able to overcome classic obstacles such as weather uncertainty and low productivity, which have been the cause of low farmers' incomes. Based on the data above, it can also be seen that the most widely used AI technologies include *machine learning*, *deep learning*, *computer vision*, and IoT sensor networks. This technology is used to read plant development, predict the weather, determine the best planting time, and monitor soil fertility levels. The variety of types of AI that appear in the table shows that its application is not limited to just one commodity or one stage of production, but covers the entire process chain in agriculture. Based on the analysis of the data above, it also appears that some issues appear repeatedly in most articles. These challenges include the high initial cost of technology, low digital literacy of farmers, inadequate network infrastructure, and lack of training for farmers. The similarity of challenges in many articles shows that AI adoption is not just a technological issue, but a structural issue involving education, policy, and the availability of supporting facilities. In addition, several journals also highlight the problem of inequality of access, where small farmers are often left behind compared to large-scale farmers.

But on the other hand, there are opportunities that show the great potential of AI to improve production efficiency, lower operational costs, and improve crop quality. Many articles note that the use of AI can improve the accuracy of decisions, such as when to fertilize, when to harvest, and how to minimize the risk of extreme weather. The opportunities written in almost all articles show that the benefits of AI far outweigh the challenges if implementation is done with the right strategy. AI can also create supply chain efficiencies, reduce production costs, and improve harvest quality. Some articles even mention that AI opens up new opportunities for connectivity between farmers and large buyers through digital platforms. This is particularly relevant for *supply chain improvement* because it allows farmers to cut through the middlemen for direct sales to consumers.

From a *supply chain* perspective, several articles show that AI can help farmers connect directly to markets and large buyers through increased price transparency and quality standards. With the help of AI, farmers can know the needs of large buyers, prepare quality according to standards, and reduce dependence on middlemen. This opens up a strong opportunity to shorten the distribution chain, so that farmers' profit margins increase. At the production level, AI is widely

used to monitor crop conditions in real-time using sensors and cameras. Based on the literature review, it is shown that the technology can help farmers make more informed decisions, such as efficient use of fertilizers and early detection of pests. With increased production accuracy, crop yield losses can be suppressed, which ultimately increases farmers' incomes and improves supply chain performance. On the other hand, some articles convey that the application of AI is often hampered by farmers' lack of ability to use digital devices. These challenges show that implementation strategies must include intensive training, mentoring, and simplification of technology for AI to be adopted by smallholders. This means that technology must not stand alone, but must be accompanied by social and institutional support.

Based on the data, the literature review highlights that AI can improve transparency throughout the distribution process. Digital platforms and prediction algorithms can show daily market prices, demand conditions, as well as quality standards required by large buyers in real-time. This transparency is very important to improve the bargaining position of farmers in the supply chain, because so far farmers often do not have adequate access to information. AI also plays a role in strengthening supply chain coordination. With a digital production record, farmers and cooperatives can develop consistent supply plans to large buyers. This can reduce the risk of goods being rejected due to non-standard quality, or unstable supply. This consistency is the main factor for large buyers such as supermarkets, the food industry, or exporters to be willing to work directly with farmers. Overall, AI adoption can be a strong foundation for creating a more efficient, equitable, and profitable agricultural supply chain for farmers. By overcoming the challenges of training and infrastructure, as well as maximizing opportunities in the form of market predictions, quality standardization, and price transparency, farmers can sell directly to large buyers and earn higher profit margins. The implementation of AI integrated with cooperatives and digital marketing has the potential to build a new supply chain model that is more modern and sustainable.



analyze crop yields, quality, and costs. This AI platform then generates a fair Decision Support & Price Prediction System, connecting farmers directly with Large Suppliers and cutting through inefficient intermediary chains. Underneath the physical flow of the product, there is a Blockchain Network Platform layer that provides transparency and security. Every transaction from farmers to Large Suppliers, to Processing, Distribution, Retailers and Consumers, is recorded using Smart Contract & Traceability, which ensures automatic payments to farmers immediately after handover and allows traceability of product origin. Other important support comes from the also connected Access to Capital, Insurance, and Investment Platforms, which leverage data verified by AI and Blockchain, as well as the role of the Government as a regulator that receives two-way data insights to make the right policies. Overall, this model creates an efficient, transparent, and fair

ecosystem that ensures product quality (Sustainability & Quality Assurance), while maximizing profits for manufacturers at the upstream level.

CONCLUSIONS AND RECOMMENDATIONS

Indonesia's agricultural sector could undergo a major overhaul through the transition from traditional supply chain systems to Digital Supply Chains that leverage Artificial Intelligence (AI) and Blockchain. The integration of this technology has significant potential to improve operational efficiency and farmers' welfare. Specifically, AI through *machine learning* and *deep learning* helps farmers make smarter decisions, such as predicting demand and managing logistics efficiently. This not only reduces crop losses, but also allows farmers to sell products directly to buyers, thereby increasing profits. On the other hand, Blockchain ensures transparency and traceability of products from farmers to consumers, builds trust, and accelerates automated payments through *Smart Contracts*. Furthermore, this digital model makes it easier for smallholders to access capital and insurance, while governments gain valuable data to design better food policies. However, its implementation is hampered by several obstacles, including uneven digital infrastructure, high initial investments, lack of digital literacy among farmers, and data quality and integration issues. Therefore, a comprehensive approach is needed that includes infrastructure investment and technology subsidy assistance, intensive training for farmers, strengthening regulations and institutions, and prioritizing the use of AI that focuses directly on increasing farmers' profits and bargaining power in the early stages of the supply chain.

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