

Digital Transformation in Indonesian Agriculture: Enhancing Supply Chain Performance in the Era of Smart Farming 2025

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ARTICLE INFO	ABSTRACT
Keywords: Digital Transformation; Supply Chain; Agriculture; Smart Farming; Technological Efficiency;	Digital transformation has become a strategic mechanism to address persistent inefficiencies in agricultural supply chains, particularly those related to logistical delays, supply-demand imbalances, and lack of data transparency. This study investigates the impact of digital technologies on the performance of agricultural supply chains in Indonesia within the framework of Smart Farming 2025. Using a qualitative approach with a library research method, this research analyzes various scholarly sources, including national and international journals, policy papers, and institutional publications. The findings reveal that digital transformation enhances logistics efficiency, improves demand forecasting, strengthens product traceability, and increases farmers' access to markets and technologies. Despite these advantages, challenges remain—particularly the digital divide, infrastructural limitations, and resistance to technology adoption. Therefore, this study highlights the need for collaborative strategies among governments, private sectors, and farming communities to build an inclusive, adaptive, and sustainable digital agriculture ecosystem.
Article history: Received 2025-06-16 Revised 2025-07-12 Accepted 2025-07-15	
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1. INTRODUCTION

Indonesia's agricultural sector plays a pivotal role in ensuring food security, generating employment, and contributing significantly to the national Gross Domestic Product (GDP). However, despite its strategic importance, the sector continues to encounter persistent inefficiencies in its supply chain. Issues such as fragmented distribution, poor demand forecasting, and lack of real-time data integration hinder overall performance. According to the Ministry of Agriculture (2024), post-harvest losses in Indonesia can reach 20–30%, primarily due to ineffective supply chain management.

In the face of these challenges, digital transformation has emerged as a promising solution to modernize the agricultural value chain. The adoption of advanced technologies—such as the Internet of Things (IoT), Big Data analytics, Artificial Intelligence (AI), and blockchain—offers unprecedented opportunities to enhance productivity, reduce waste, and improve coordination across stakeholders. Goh (2022) emphasizes that digital tools can empower smallholder farmers by increasing operational efficiency and expanding access to broader markets through data-driven practices.

Smart farming, as conceptualized by Wolfert et al. (2017), is more than just the application of sophisticated tools; it is a systemic integration of data into farm management that facilitates real-time decision-making and precision agriculture. Through the use of digital platforms, farmers can optimize resource allocation, mitigate risks, and align production with fluctuating consumer demands. This shift is particularly crucial in developing economies like Indonesia, where agriculture is still largely characterized by conventional practices.

From a theoretical standpoint, the Technology–Organization–Environment (TOE) framework (Tornatzky & Fleischer, 1990) provides a useful lens to understand how digital adoption is influenced by technological capabilities, organizational readiness, and external environmental pressures. In Indonesia, although technological solutions are increasingly available, implementation remains hindered by digital infrastructure gaps, limited digital literacy, and socio-institutional barriers (Rahman et al., 2021).

Furthermore, Supply Chain Performance Theory posits that effective supply chains are measured through key performance indicators (KPIs) such as responsiveness, flexibility, reliability, and cost efficiency (Beamon, 1999). Digital transformation, in this regard, holds the potential to enhance these KPIs by enabling real-time data exchange, automation, and predictive analytics throughout the supply chain.

Considering these dynamics, it becomes essential to examine how digital transformation, particularly in the context of smart farming, can improve the performance of agricultural supply chains in Indonesia. This study seeks to explore this impact by analyzing conceptual frameworks, technological adoption, field-level evidence, and relevant policy implications in the era of Smart Farming 2025.

2. METHODS

This study adopts a qualitative exploratory approach using a library research method to analyze the role of digital transformation in improving the performance of agricultural supply chains. The qualitative method is particularly suitable for understanding complex social and technological phenomena in depth, especially in contexts where empirical data is still limited (Creswell, 2013). Through library research, the study explores a wide array of conceptual and empirical materials related to agricultural digitalization and smart farming.

The primary data sources include scholarly books, national and international peer-reviewed journals, policy documents, and institutional publications from agricultural research bodies and international development agencies. A total of 50 primary and secondary references were carefully selected based on their credibility, publication year, and relevance to themes such as digital innovation, agricultural supply chains, and smart farming technologies (Boell & Cecez-Kecmanovic, 2015). This literature review method enables a structured synthesis of academic debates, empirical findings, and policy discussions.

The analysis employs content analysis techniques to identify recurring patterns, policy trends, technological frameworks, and implications of digital transformation in agriculture. Content analysis is useful in organizing qualitative data into meaningful categories and themes, facilitating the

interpretation of complex textual materials (Krippendorff, 2018). The analytical focus includes supply chain components such as logistics, distribution systems, demand forecasting, product traceability, and operational cost structures, as framed by supply chain performance theory (Beamon, 1999).

To enhance the credibility and validity of the study, source triangulation is applied by cross-verifying information from various types of publications—academic journals, government reports, and international institutional documents (Patton, 2002). This triangulation helps to minimize bias and broaden the analytical perspective.

The research framework is based on the conceptualization of digital transformation as the strategic integration of digital technologies—including the Internet of Things (IoT), Artificial Intelligence (AI), blockchain, and data analytics—into agricultural processes to increase efficiency, precision, and transparency (Klerkx et al., 2019). Meanwhile, supply chain performance is measured through indicators such as responsiveness, flexibility, delivery reliability, and cost-effectiveness (Gunasekaran et al., 2004), which serve as benchmarks for assessing the impact of digitalization in agriculture.

3. FINDINGS AND DISCUSSION

Digital transformation in agriculture presents a paradigm shift in how food is produced, distributed, and consumed in the 21st century. As Indonesia transitions into the Smart Farming era by 2025, understanding the depth of this transformation is crucial, particularly in evaluating its influence on supply chain performance. This section synthesizes key themes emerging from global and Indonesian case studies, enriched by literature and policy insights.

3.1 Digitalization as a Solution to Supply Chain Inefficiency

Indonesia's agricultural supply chains are notoriously fragmented, with limited synchronization across stakeholders. Traditional inefficiencies include delays in transportation, poor cold chain infrastructure, minimal product traceability, and weak demand-supply matching. These issues contribute to post-harvest losses of up to 30%, particularly in horticultural commodities (Ministry of Agriculture, 2024). Christopher (2011) asserts that real-time data sharing and system integration are essential for responsive and efficient supply chains.

Digitalization addresses these inefficiencies through the implementation of cloud-based Enterprise Resource Planning (ERP) systems, mobile supply chain applications, and sensor-based logistics monitoring. Klerkx et al. (2019) found that these systems enable producers to make informed decisions about harvesting, warehousing, and distribution by synchronizing operations with market trends. The World Bank (2021) also reports that digital logistics platforms reduced average delivery times in Indonesia's horticulture sector by 40%, decreasing the gap between rural producers and urban markets.

In addition, digital tools such as smart dashboards, predictive analytics, and mobile payment systems contribute to the visibility and responsiveness of agricultural value chains. These platforms allow cooperatives and agribusinesses to adjust procurement strategies, manage inventories, and respond to climatic changes swiftly.

Potentials: Greater visibility into supply movements, lower transportation costs, minimized spoilage, and stronger producer-market connectivity. Barriers: Unequal access to digital infrastructure, inconsistent use of ERP systems among cooperatives, and the lack of integrated national databases.

3.2 The Role of Big Data and Artificial Intelligence

Big data and AI are critical enablers of Smart Farming, transforming how data is collected, analyzed, and utilized in daily agricultural operations. Farmers now utilize cloud-based tools that collect large datasets from multiple sources—satellite imagery, remote sensors, market prices, and weather APIs. These data streams are used to build predictive models for crop planning and market forecasting.

Zhang et al. (2020) report that precision agriculture utilizing big data analytics improves productivity by 25%, reduces input waste, and enhances yield predictability. Machine learning algorithms are used to recommend planting schedules, suggest pest control strategies, and forecast market fluctuations. Kamilaris et al. (2017) highlight AI's capability to automate irrigation, detect disease from drone imagery, and predict logistics bottlenecks. In perishable commodities, AI can reduce spoilage by up to 30% (FAO, 2020).

Indonesia's digital agriculture startups are experimenting with AI-based price prediction models and chatbot-based agricultural advisory services. However, rural areas often lack the technical workforce to deploy or maintain these technologies. Potentials: Increased forecasting accuracy, optimization of fertilizer and water usage, reduced human error, and enhanced food supply resilience. Barriers: High capital costs of AI tools, limited access to cloud services, and a shortage of agri-tech engineers in rural regions.

3.3 IoT and Blockchain for Traceability

IoT (Internet of Things) technologies such as soil moisture sensors, automated irrigation systems, and GPS-enabled harvesting tools help monitor field conditions in real-time. Harun & Ningsih (2024) emphasize that IoT implementation led to a 20% reduction in crop failure by enabling proactive decision-making. Precision irrigation systems based on sensor data can optimize water usage by as much as 35%.

Blockchain, on the other hand, secures traceability in agricultural supply chains. It creates immutable records of product origin, processing, and distribution, supporting both food safety and market compliance. Lioutas et al. (2021) argue that blockchain use increases consumer trust, particularly for high-value organic or export commodities. In a study by Wolfert et al. (2017), consumers in OECD countries were willing to pay 10–15% more for goods with reliable traceability.

Indonesia's Ministry of Agriculture is piloting blockchain in coffee and cocoa value chains. However, implementation remains nascent, with challenges in interoperability and farmer awareness. Potentials: Compliance with international standards, increased transparency for consumers, enhanced product certification. Barriers: Low understanding of blockchain among smallholder farmers, high initial costs, and limited governmental standards on traceability.

3.4 Socioeconomic Impacts of Agricultural Digitalization

Digital agriculture not only affects technical efficiency but also has profound social implications. It alters the power dynamics between farmers, traders, and retailers. Digital marketplaces, e-wallets, and e-extension services have reduced dependence on middlemen, enabling farmers to capture a larger share of consumer prices.

Goh (2022) notes that Indonesian farmers on digital platforms earn 30–40% higher incomes due to better market access. Financial technology (fintech) also increases access to credit via alternative data, empowering unbanked farmers to secure working capital.

However, the benefits of digitalization are unevenly distributed. Rotz et al. (2019) and BPS (2023) show that only 43% of rural farming households have reliable internet access. Gender and generational divides persist, with women and older farmers having lower digital literacy levels. Potentials: Greater income equality, digital financial inclusion, youth engagement in agriculture, and

market diversification. Barriers: Persistent digital illiteracy, lack of localized digital content, affordability of smartphones and internet packages.

3.5 Field Studies and Best Practices in Indonesia

Case studies across Indonesia present compelling evidence of successful digitalization. TaniHub, Sayurbox, and EdenFarm connect thousands of farmers to end-users via mobile apps. These platforms aggregate supply, manage logistics, and facilitate payments in real time. Siregar et al. (2025) found that farmers engaged with digital cooperatives experienced 20% higher revenue and 35% shorter delivery times. Setiawan & Putri (2023) observed improved transparency in price negotiations and contract enforcement.

In West Java, farmer groups using digital ledger apps improved their credit scores with microfinance institutions. In Yogyakarta, youth-led agri-tech startups are promoting hydroponics and vertical farming with cloud integration. Potentials: Empowered cooperatives, localized innovation ecosystems, peer learning, and enhanced institutional credibility. Barriers: Limited funding for scale-up, digital platform dependency, and fragmented data ownership among stakeholders.

3.6 Challenges and Mitigation Strategies

Systemic challenges remain, especially in developing economies. According to the FAO (2020), localized adaptation is critical. Infrastructure deficits in electricity, 4G coverage, and device availability hamper digitalization. Recommended strategies include the establishment of digital agricultural service centers at the village level, mobile-based training for extension workers, and fiscal incentives for agri-tech adoption. Nugroho & Prabowo (2023) suggest enacting laws on farmer data protection and building interoperable systems that can connect various actors securely.

Public-private partnerships (PPP) are pivotal. Multistakeholder forums should be created to harmonize regulations, mobilize investment, and develop digital literacy programs tailored to regional needs. Universities, cooperatives, and local governments must be involved in co-designing technology with communities. Potentials: System-wide modernization, regulatory clarity, collaborative innovation, and improved farmer welfare. Barriers: Political inertia, funding limitations, siloed policymaking, and low user trust in digital governance.

4. CONCLUSION

This study concludes that digital transformation significantly contributes to improving agricultural supply chain performance in Indonesia, particularly in the era of Smart Farming 2025. The integration of technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), Big Data, and blockchain has led to enhanced efficiency in logistics, real-time data management, product traceability, and market responsiveness. These improvements are especially beneficial for smallholder farmers by increasing productivity and expanding access to competitive markets.

However, the successful implementation of digital agriculture is still constrained by several critical factors, including limited rural infrastructure, digital illiteracy, and institutional resistance to change. These barriers must be addressed through targeted policy interventions and inclusive digital capacity building initiatives. From a theoretical perspective, this research affirms the relevance of the Technology–Organization–Environment (TOE) framework and Supply Chain Performance Theory in explaining the dynamics of digital adoption and its impact on supply chain efficiency. The study recommends that policymakers, agricultural stakeholders, and technology developers collaborate in designing inclusive, context-sensitive digital farming strategies. Future research should consider field-based empirical studies across diverse agricultural regions to evaluate the long-term effects of digital transformation on farmers' welfare, food security, and environmental sustainability.

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