

AGRICULTURAL SUPPLY CHAIN DIGITALIZATION AND VALUE CREATION FOR SMALLHOLDER PRODUCERS

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Abstract

The digitalization of agricultural supply chains represents a strategic approach to enhancing distribution efficiency, market access, information transparency, and value creation for smallholder farmers. However, limited access to technology, low digital literacy, uneven infrastructure development, and relatively weak bargaining power remain obstacles to realizing the economic benefits of digital transformation. This study aims to analyze the role of agricultural supply chain digitalization in creating value for smallholder farmers and to identify the factors supporting its successful implementation. A literature review approach was employed, examining various scholarly studies on supply chain digitalization, agricultural digital platforms, market access, operational efficiency, and value creation for smallholder farmers. The findings indicate that digitalization can bolster value creation by improving access to market information, reducing transaction costs, optimizing distribution, enhancing product traceability, and expanding access to consumers and financial institutions. Beyond these benefits, the effectiveness of digitalization is heavily influenced by infrastructure readiness, farmers' digital competence, technology affordability, the quality of the institutional ecosystem, and policy support. Thus, the digitalization of agricultural supply chains serves not only as a tool for efficiency but also as a mechanism to strengthen the economic position of smallholder farmers and increase their participation in more inclusive and sustainable agricultural value chains.

Keywords: Agricultural Digitalization, Agricultural Supply Chain, Smallholder Farmers, Value Creation, Market Access, Digital Transformation

INTRODUCTION

The agricultural sector plays a vital role in supporting food security, providing employment, and serving as a source of income for communities across various regions (Madushan Fernando et al., 2026). Within this sector, smallholder farmers contribute significantly to agricultural commodity production yet simultaneously face various constraints regarding access to markets, information, technology, financing, and distribution networks. These

challenges are compounded when agricultural supply chains involve numerous actors—ranging from farmers, collectors, traders, and processors to distributors and consumers. Lengthy distribution chains can lead to increased transaction costs, information asymmetry, distribution delays, and limited ability for farmers to capture proportionate economic value from their produce. This situation demonstrates that merely increasing agricultural productivity is insufficient to improve farmers' well-being unless accompanied by improvements to supply chain systems and access to more efficient markets (Mikhailov et al., 2022).

Advancements in digital technology offer new opportunities to address some of these issues (Wang et al., 2025a). The digitalization of agricultural supply chains enables processes such as production, collection, processing, distribution, marketing, and transactions to operate with the support of more integrated information technology. Digital platforms, agricultural apps, market information systems, e-commerce, digital payments, Internet of Things (IoT) technology, data analytics, and product tracking systems can help connect farmers with various value chain actors more rapidly and transparently (Smidt & Jokonya, n.d.). Real-time access to information allows farmers to obtain data on prices, market demand, product quality, distribution conditions, and marketing opportunities. Digitalization also enhances product traceability, making information regarding origins and production processes accessible to both supply chain actors and consumers. In this context, digital technology serves not only as a communication tool but also as infrastructure that supports coordination and value creation throughout the agricultural supply chain (Piot-Lepetit, 2025).

However, the benefits of digitalization are not automatically distributed equitably among smallholder farmers. Disparities in the ability to access and utilize technology can create a digital divide between farmers with adequate resources and those located in regions or groups with limited infrastructure. Factors such as internet connectivity, ownership of digital devices, technology usage costs, digital literacy, information management skills, and trust in digital platforms determine the success of digital transformation in the agricultural sector. Beyond technological issues, the characteristics of small-scale farmers—whose operations are relatively limited in scope—can also influence their ability to adapt to digital systems (Masi et al., 2025a). Therefore, digitalization should be understood not merely as the adoption of devices or applications, but as a transformation in how agricultural stakeholders acquire

information, build business relationships, conduct transactions, manage resources, and generate economic value.

Value creation is a crucial aspect of the discourse on the digitalization of agricultural supply chains. Historically, the economic value generated by agricultural products has often been unevenly distributed among supply chain participants. As primary producers, farmers frequently face limitations in price setting due to their reliance on specific marketing channels and a lack of information regarding market conditions (Rayhan et al., 2024). Digitalization has the potential to alter this pattern by opening up more diverse marketing channels and enabling farmers to interact more directly with buyers, processors, business entities, and consumers. Access to digital markets can help expand marketing reach, reduce dependence on specific distribution channels, and provide opportunities to secure prices that better reflect product quality and demand conditions. Furthermore, the ability to generate and utilize data can enhance decision-making regarding production, inventory, sales timing, and distribution (Klingenberg et al., 2022).

Digitalization is also linked to supply chain efficiency and sustainability. Integrated information can help reduce uncertainty in production and distribution planning, while digital monitoring systems can improve coordination among stakeholders. Improved data management allows for the rapid identification of market needs and potential supply chain disruptions. Additionally, digital systems that support traceability can enhance transparency regarding product quality, safety, and origin. These factors are increasingly relevant as consumers and markets place greater emphasis on sustainability, quality, and responsible production processes (Fernando et al., 2024). Thus, digitalization holds the potential to create economic value while simultaneously strengthening transparency and efficiency within agricultural supply chains.

However, the implementation of digitalization also presents several challenges that require attention. Reliance on digital platforms can raise issues concerning data ownership and management, transaction security, privacy, and the bargaining power of users vis-à-vis platform providers. If the digital ecosystem is dominated by a select few actors, digitalization could inadvertently create new forms of dependency for smallholder farmers (Gumbi et al., 2023a). Therefore, successful digital transformation requires a supportive ecosystem—including adequate digital infrastructure, enhanced farmer capacity and digital literacy, robust institutional frameworks, inclusive business models, data protection, and policies ensuring that the benefits of digitalization are accessible to diverse agricultural stakeholders. This approach is crucial to

ensure that digital transformation not only drives efficiency for companies or distributors but also tangibly contributes to increasing the value realized by farmers (Tombe & Smuts, 2023a).

Given this context, research into the digitalization of agricultural supply chains and value creation for smallholder producers is highly relevant. Supply chain digitalization requires comprehensive analysis, examining the interplay between technology, information access, transaction efficiency, market access, traceability, supply chain coordination, and the ability of farmers to capture and sustain economic value. This study aims to understand how digitalization can serve as a tool to strengthen the position of smallholder farmers within the agricultural value chain, while also identifying factors that facilitate or hinder value creation through digital transformation. Through this approach, the research is expected to provide conceptual insights into the relationship between supply chain digitalization and value creation, serving as a foundation for developing agricultural digital transformation strategies that are more inclusive, efficient, and sustainable.

RESEARCH METHODS

This study employs a literature review approach to analyze the role of agricultural supply chain digitalization in creating value for smallholder farmers. Research data were obtained from various relevant scholarly sources—primarily national and international journal articles—addressing topics such as agricultural supply chain digitalization, digital technologies in agriculture, market access, supply chain efficiency, value creation, and the empowerment of smallholder farmers. Literature was gathered through academic database searches using keyword combinations such as "agricultural supply chain digitalization," "digital agriculture," "smallholder producers," "value creation," "market access," and "digital transformation." Selected literature was evaluated based on topical relevance, source quality, alignment with research objectives, and its contribution to explaining the relationship between digital technology adoption and value creation within agricultural supply chains. A descriptive-qualitative analysis was conducted by identifying, categorizing, comparing, and synthesizing findings from prior research to uncover patterns, benefits, challenges, and enabling factors associated with supply chain digitalization for smallholder farmers. The resulting synthesis serves to build a more comprehensive understanding of digitalization mechanisms that enhance information and market access, reduce transaction costs, strengthen supply

chain coordination, improve product traceability, and support the creation of more inclusive and sustainable economic value for smallholder farmers.

RESULTS AND DISCUSSION

The Role of Digitalization in Enhancing Agricultural Supply Chain Efficiency and Transparency

Digitalization has transformed the management of agricultural supply chains, particularly regarding information exchange, coordination among stakeholders, distribution management, and product movement monitoring (Charlebois et al., 2024). In conventional supply chain systems, information concerning prices, demand, product availability, quality, and distribution conditions is often fragmented across farmers, traders, aggregators, distributors, and consumers. Such information asymmetry can lead to delayed decision-making and increased coordination costs. The use of digital technology enables the rapid collection, storage, and sharing of information, providing supply chain actors with a stronger informational basis for making production and distribution decisions (Stanescu et al., 2025). For smallholder farmers, access to digital information can also reduce reliance on information obtained solely through intermediaries, allowing marketing decisions to be made more rationally.

Digital platforms serve as a crucial instrument for improving agricultural supply chain efficiency. These platforms connect farmers with buyers, input providers, processing companies, distributors, and consumers through more integrated transaction mechanisms. Digitalization allows ordering, transaction recording, payment, and business communication processes to be executed more rapidly than conventional methods. Reducing administrative tasks and repetitive communication has the potential to lower transaction costs and accelerate the flow of products from producers to the market (Abiri et al., 2023). Furthermore, market demand information available via digital platforms helps farmers align their marketing volumes and timing with market conditions. Thus, efficiency relates not only to distribution speed but also to the ability of each actor to allocate resources based on more relevant information.

The implementation of information systems and data-driven technologies further strengthens supply chain management capabilities (Bekkouche & de-Magistris, 2025). Data regarding production, inventory, prices, demand, location, and distribution can be used to identify patterns and potential disruptions within the supply chain. For supply chain managers, the availability of integrated data supports requirements planning, inventory management,

and distribution scheduling. For farmers, such information serves as a basis for decisions regarding harvest timing, sales volumes, and the selection of marketing channels. Leveraging data analytics also enables stakeholders to anticipate demand fluctuations and mitigate the risk of a mismatch between production levels and market needs (Dong et al., 2023). Consequently, digital transformation can foster more responsive decision-making processes while reducing the uncertainty that has long characterized agricultural activities.

Internet of Things (IoT) technology adds a new dimension to supply chain management by enabling the continuous collection of data on the physical condition of products and their environment (Wang et al., 2025b). Sensors can monitor various parameters related to production, storage, and transportation such as temperature, humidity, location, and other environmental factors. This information allows supply chain actors to detect changes in product conditions early on, facilitating corrective actions before significant damage occurs. This is particularly relevant for perishable agricultural commodities that require specialized handling during distribution. Through consistent monitoring, IoT adoption helps minimize potential post-harvest losses, improve the quality of products reaching the market, and enhance resource efficiency across the supply chain.

Beyond efficiency, digitalization plays a crucial role in enhancing the transparency and traceability of agricultural products. Digital systems enable the systematic recording of information regarding product origins, production processes, delivery times, distribution locations, and transactions (Otter & Robinson, 2024). The availability of such information empowers business actors and consumers to track a product's journey from the producer to the market. Traceability is becoming increasingly vital in a market landscape where quality, food safety, and sustainability are key consumer considerations. For smallholder farmers, inclusively designed traceability systems offer an opportunity to showcase the quality and characteristics of their produce, thereby providing stronger supporting information when entering markets that demand specific standards.

However, the impact of digitalization on efficiency and transparency is not determined solely by the presence of technology. These benefits depend heavily on data quality, system interoperability, user capabilities, infrastructure availability, and the willingness of various actors to share information. Non-integrated digital systems can lead to data fragmentation, while limited digital literacy may hinder farmers' ability to utilize available information (Keefe et al., 2024). Therefore, the digitalization of agricultural supply chains should be

developed as an ecosystem that integrates technology, human resources, institutional frameworks, and information governance. From a value-creation perspective, digitalization yields broader benefits when the resulting gains in efficiency and transparency are not limited to downstream actors but also improve the access and standing of smallholder farmers within the entire agricultural value chain. Through this approach, digital technology can serve as an instrument to build supply chains that are more coordinated, transparent, and responsive, ultimately delivering more inclusive value for all agricultural stakeholders.

Digitalization and Value Creation for Smallholder Farmers through Market and Information Access

The digitalization of agricultural supply chains offers smallholder farmers opportunities to expand their access to information and markets—access previously constrained by distance, costs, and reliance on conventional marketing channels (Choruma et al., 2024a). In traditional agricultural systems, farmers often obtained information on prices and demand through local networks or intermediaries who possessed broader market access. This situation could lead to information asymmetry between producers and buyers, limiting farmers' ability to determine the timing and channels of their sales. The use of digital technology enables faster access to information regarding commodity prices, market demand, product quality, and marketing opportunities. Such information helps farmers understand market conditions and make marketing decisions based on up-to-date data, ensuring that value creation is not solely dependent on relationships with specific intermediaries (Tombe & Smuts, 2023b).

Digital platforms also open up opportunities for smallholder farmers to access a more diverse range of marketing channels. The emergence of electronic marketplaces, agricultural trading apps, digital media, and platform-based marketing systems allows agricultural products to be offered to buyers across a wider geographical area (Gumbi et al., 2023b). This shift can reduce the geographical barriers that previously limited farmers to markets near their production sites. Farmers are no longer restricted to local markets; instead, they have the opportunity to build relationships with traders, processors, companies, and end consumers via digital channels. Such diversification of marketing channels offers flexibility in identifying potential buyers and tailoring sales strategies to product characteristics and market demand (Njuguna et al., 2025a). In terms of value creation, broader market access increases the

likelihood of products realizing economic value based on their quality, quantity, and specific attributes.

Direct access to consumers is a crucial aspect of this transformation. Digital technology enables farmers to establish communication and business relationships with consumers without always relying on lengthy chains of intermediaries (Njuguna et al., 2025a). Information regarding product origins, production methods, quality, and commodity characteristics can be conveyed to consumers through social media, e-commerce, and specialized agricultural product platforms. Such interactions go beyond mere transactions; they also foster trust and enhance product recognition. For agricultural products with distinctive attributes such as local goods, specific quality grades, or items meeting sustainability standards digital communication serves as a vehicle to convey value-added propositions to the market (Tabe-Ojong et al., 2024). Consequently, value creation can evolve from simple production activities into the management of information and consumer relationships.

Digitalization also holds the potential to expand smallholder farmers' access to financial services and credit. Digital payment systems and technology-driven financial services can streamline transactions and open avenues for farmers to connect with a range of financial offerings. Digitally documented data on business activities, transactions, and sales history can support the establishment of relationships with financial institutions, although access remains subject to the requirements and mechanisms enforced by service providers. Furthermore, the ease of transacting can improve payment collection efficiency and reduce reliance on cash transactions. In the long term, integrating marketing platforms with financial services can create an ecosystem that supports farmers' economic activities in a more structured manner (Masi et al., 2025b).

Improved access to information and markets can, in turn, influence farmers' bargaining power within the value chain. When farmers possess better information regarding prices, demand, quality, and alternative buyers, their reliance on a single marketing channel can be reduced. This situation affords farmers greater scope to compare marketing options and determine sales strategies suited to their business conditions. However, digitalization does not automatically guarantee enhanced bargaining power, as this capacity is also shaped by factors such as production scale, product quality, negotiation skills, logistics access, and market structure (Exploring the Impact of Agricultural Digitalization on Smallholder Farmers' Livelihoods in Ghana: Heliyon, n.d.). Consequently, digital technology must be coupled with the strengthening of

production capacities, farmer institutions, and managerial skills to ensure that available information can be effectively translated into economic benefits.

From a value-creation perspective, the primary benefit of digitalization for smallholder farmers lies in its ability to link information, markets, transactions, and business relationships within a more integrated ecosystem. Digitalization can help bridge information gaps, expand market choices, enhance transaction efficiency, and create opportunities for more direct relationships between producers and consumers. Yet, sustainable value creation requires digital governance that ensures farmers have affordable access and the ability to use technology, alongside protection against risks associated with data usage and platform dependency. Therefore, the digitalization of agricultural supply chains should be steered toward inclusive models, ensuring that the economic benefits of improved market and information access reach smallholder farmers the primary producers rather than accruing solely to actors who control the technology and marketing networks. With adequate support in infrastructure, digital literacy, institutional frameworks, financing, and policy, digital technology has the potential to serve as a vital instrument for strengthening smallholder farmer participation and enhancing opportunities for value creation within the agricultural value chain.

Challenges and Strategies for Strengthening Inclusive and Sustainable Supply Chain Digitalization

Although digitalization offers opportunities to enhance efficiency and value creation within agricultural supply chains, its implementation among smallholder farmers still faces various obstacles. Limited digital infrastructure is a fundamental issue, particularly in rural areas lacking adequate internet network quality and communication access (Choruma et al., 2024b). Such conditions can restrict farmers' ability to utilize marketing platforms, market information systems, digital financial services, and data-driven monitoring technologies. Infrastructure disparities also risk creating a gap in the benefits of digitalization between farmers in areas with high connectivity and those in regions with limited technological access (Tombe & Smuts, 2023c). Therefore, the success of digital transformation in agricultural supply chains cannot be measured solely by the volume of technology deployed, but also by the ability of diverse farmer groups to access and benefit from these technologies.

Beyond infrastructure, levels of digital literacy and competence are critical determinants of technology usage effectiveness. Smallholder farmers may possess digital devices yet lack the skills to utilize them optimally.

Difficulties in operating applications, interpreting digital information, conducting online transactions, managing data, or recognizing digital security risks can diminish the benefits derived from this transformation. Costs associated with device acquisition, connectivity, platform services, and technology maintenance can also pose barriers for farmers with limited economic means. These conditions underscore the need for digitalization strategies to account for users' economic capabilities and capacities, ensuring that introduced technologies do not impose new burdens on smallholder farmers (Gumbi et al., 2023c).

Issues regarding data security and platform dependency also require attention during the development of agricultural digital ecosystems (Njuguna et al., 2025b). Digitalization results in the collection of increasing amounts of data covering production, transactions, prices, locations, and business activities through various systems. If data governance lacks transparency, farmers may face limitations in understanding how their data is used, stored, and shared. Reliance on a single platform can also create risks such as when farmers lack alternative marketing channels or when service fees and terms of use change (Kitole et al., 2024). In this context, fostering sustainable digitalization requires adherence to principles of transparency, security, and interoperability, alongside the protection of user interests. Farmers must be viewed not merely as technology users, but as stakeholders who hold rights and interests regarding the data generated through their business activities.

Strategies to strengthen digitalization must begin with enhancing farmers' capacities. Digital literacy programs should go beyond technical training on app usage; they must also encompass skills such as interpreting market information, conducting secure transactions, managing business data, utilizing digital financial services, and recognizing potential risks in the digital environment. A continuous training approach tailored to the specific characteristics of farmers will better facilitate the integration of technology into their daily activities. Strengthening farmer groups and cooperatives can also serve as a vital mechanism, as collective technology adoption can help reduce costs, bolster bargaining power, and streamline knowledge exchange among stakeholders (Masi et al., 2025c).

Institutional support and digital infrastructure development are also crucial components in fostering inclusive transformation. Governments, educational institutions, farmer organizations, financial institutions, technology companies, and supply chain stakeholders can collaborate to provide affordable technology access tailored to local needs. Internet infrastructure

expansion must go hand-in-hand with the provision of user-friendly digital systems capable of integrating with various platforms. Developing interoperable systems will reduce information fragmentation and facilitate the effective flow of data among supply chain actors. Simultaneously, support organizations can assist farmers in understanding technology while connecting them to markets and relevant sources of financing (Nwangwu et al., 2024).

Public policy plays a strategic role in ensuring that digital transformation does not widen economic disparities within the agricultural sector. Policies need to promote equitable infrastructure distribution, enhanced digital literacy, data protection, transaction security, and healthy platform competition. Financial support or incentive schemes could also be considered to help smallholder farmers manage the initial costs of technology adoption. Furthermore, policies should encourage digitalization models that position farmers as active participants in the value-creation process, rather than merely passive users. Through a combination of adequate infrastructure, competency building, robust institutions, responsible data governance, and inclusive policies, the digitalization of agricultural supply chains can be developed more sustainably. This approach ensures that the benefits of technology are reflected not only in improved distribution efficiency but also in expanded market access, strengthened farmer capacity, and the creation of more equitable economic value throughout the agricultural supply chain.

CONCLUSION

The digitalization of agricultural supply chains plays a crucial role in enhancing efficiency, transparency, and value creation for smallholder farmers. Literature reviews indicate that the use of digital platforms, information systems, the Internet of Things (IoT), and data-driven technologies can accelerate information exchange, improve coordination among stakeholders, reduce transaction costs, support distribution management, and enhance the traceability of agricultural products. Digitalization also creates opportunities for smallholder farmers to obtain price and demand information more quickly, expand marketing channels, reach a more diverse range of consumers and buyers, and access digital financial services. These factors can strengthen farmers' decision-making capabilities regarding marketing and increase their chances of capturing greater economic value within the agricultural value chain.

However, the benefits of digitalization cannot be fully realized without the support of an inclusive and sustainable ecosystem. Challenges such as infrastructure limitations, low digital literacy, technology adoption costs, data

security and governance, access disparities, and potential platform dependency must be addressed. Therefore, advancing digitalization requires efforts to enhance farmers' capacity and digital literacy, develop equitable infrastructure, strengthen farmer institutions, provide affordable and user-friendly technology, and implement policies that support data protection and fair access to the digital ecosystem. Through this approach, supply chain digitalization aims not only to boost efficiency but also to strengthen the position of smallholder farmers within the value chain, expand market access, and foster more inclusive and sustainable economic value creation.

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