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The Role of Digital Innovation and Agritech Startups in Strengthening Food Supply Chain Resilience in Sub-Saharan Africa: A Systematic Literature Review

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Abstract

The purpose of this systematic literature review is to investigate how digital innovations, including blockchain, the Internet of Things (IoT), ICT services, and agritech startup interventions, can improve the resilience of food supply chains throughout Sub-Saharan Africa is the main topic of this review of the literature. Considering new or established technologies (like artificial intelligence, sensors, precision fermentation, robotics, nanotechnologies, and genomics) that make up Agriculture 4.0 and Food 4.0, AgriFoodTech start-ups are increasingly being recognized as important participants in the discussion and actualization of the transformation of food systems. In major academic databases, we searched for empirical and conceptual research published between 2020 and 2025 on the effects of the aforementioned technology on agro-food chains that have been disrupted by the COVID-19 epidemic, conflict, climate change, and infrastructure shortages. According to the main conclusions, the food supply chain may be made more transparent and traceable through the use of blockchain technology and the Internet of Things (IoT). Information and communication technology (ICT) services that are mobile-based also improve market information flow and accessibility. Agritech firms have the potential to accelerate the adoption of innovations, according to encouraging data, but there are also structural issues with infrastructure, cost, and regulatory frameworks. In order to create innovation-driven, resilient, and egalitarian food systems in unstable contexts, this study combines resilience results with established barrier and enabler structures and provides helpful frameworks to improve the digital-entrepreneurial ecosystem. In vulnerable circumstances, the study shows how the interaction of digital space, startup ecosystems, and systemic issues results in the development of effective infrastructures.

Keywords: Digital Innovation, Agritech Startups, Food Supply Chain Resilience, Sub-Saharan Africa, Systematic Literature Review

1. Introduction

In Sub-Saharan Africa (SSA), agriculture is an integral part of the economy, employing about 60–90% of the population and accounting for nearly 20–30% of the GDP for the region. Nonetheless, the agriculture industry continues to face acute challenges, including disjointed supply chains, systemic and structural inefficiencies within the industry, food wastage, and climate change, all of which jeopardize food security and the sustenance of rural livelihoods (Fridah Gitau 2024). The adoption of digital technologies into agriculture, which is the use of blockchain technology, the Internet of Things (IoT), AI, and mobile ICTs, has recently evolved to be an all-encompassing shift in the food value chain from farm-level precision to logistics. Such technologies come with advantages related to better efficiency, lower costs, and improved smallholder market access while enhancing traceability and removing middlemen, as highlighted by empirical studies (IEEE 2025). In particular, the blockchain – IoT nexus illustrates great potential for improving transparency and alleviating vulnerabilities along the food chain. A recent feasibility study illustrates the potential blockchain has in creating immutable records for capturing the product's origin and the IoT devices' capability in monitoring the environment in real-time, which helps mitigate issues like contamination and inefficiencies. Furthermore, SSA focused review articles highlight the potential of integrated blockchain platforms, coupled with smart contracts and sensor networks, to resolve the traceability issues, enhance trust among farmers, and reduce post-

harvest losses (Mwewa *et al*., 2025) [15]. Globally, blockchain has shown that technology has the power to completely transform sectors including logistics, healthcare, and banking. Its uses are similarly revolutionary in the agricultural industry. Through transaction automation, a decrease in the need for middlemen, and the ability for stakeholders to share data in real time, blockchain improves supply chain efficiency. Because blockchain technology is immutable, it produces a reliable record of all supply chain operations, encouraging accountability and lowering fraud (Cao *et al*., 2022). This greatly improves transparency. Furthermore, strong traceability is guaranteed by blockchain, enabling stakeholders to follow agricultural products from farm to table. Meeting export market demands and resolving consumer concerns regarding the safety and quality of food depend heavily on this capability. In any case, the replication and scaling of these technologies in SSA are still hampered by these critical gaps. Insufficient infrastructure, such as unreliable electricity and poor internet connectivity, high implementation costs, lack of appropriate regulatory frameworks, and limited technical skills among farmers are often mentioned as major challenges. In addition, the challenges are compounded by the digital divide, underscoring the need for more enabling policy frameworks and innovation(Arthur *et al*., 2024) [1].

In the past few decades, it has become transparent that food systems have reached or surpassed many of their planetary boundaries. To ensure food security, create more resilient and equitable food systems, and achieve sustainability, food systems must undergo a radical transformation (Springmann *et al*., 2018; Willett *et al*., 2019). Food insecurity is still a problem in Africa, where the agricultural sector is less developed. Despite the continent's wealth of natural resources and promising agricultural potential, several nations nevertheless import food on a net basis (Ayim *et al*., 2020) [2]. According to a 2015 study by the African Development Bank, the continent imports over US$25 billion worth of food crops every year (Moyo, Bah, & Verdier-Chouchane). Post-harvest losses are high (averaging around 30% of total production in sub-Saharan Africa alone), and the authors claim that there is little value addition and processing of agricultural commodities. Nonetheless, the continent's agriculture industry continues to be important. It provides the majority of its rural residents with their primary source of income. The agricultural industry is responsible for around 75% of domestic commerce and nearly two-thirds of all jobs (World Bank, 2008). Since agriculture is the primary source of income for most rural residents, the sector's expansion and advancement are vital.

Through the efficient use of information and communication technology (ICT), the agriculture sector can grow and develop. In nations and industries where they are effectively implemented, ICT has significantly boosted growth and socioeconomic development, according to the Food and Agriculture Organization (FAO, 2017). Agricultural value chain productivity and efficiency have increased significantly as a result of the successful integration of ICT in the agricultural sector in both American and European nations. For example, traceability technologies like radio frequency identification (RFID) and blockchain have made it possible to track and trace food from farm to fork, enabling efficiency and transparency across the food chain. The use of robotic drones for data and image collection, Uber for tractor application software, which is frequently used by farmers to hire tractors for their farm activities [35], INSPIRE hackathons and Smart AfrihuB, which aim to train and equip farmers with the necessary knowledge and skills [36], and Farm Crowdy, which aims to revitalize the agribusiness industry in Africa by connecting farmers with potential investors and other actors within the agricultural value chain [37] are some of the common digital innovations within the agribusiness sector in Africa. Typical examples of unique and pertinent digital innovation platforms that provide digital solutions and training for several actors in the agricultural sector include Agri Map, Agribook, AgriLeap, AgriYara, Fupro, Afrique Learning, and Zoom Agro [38]. In general, the agribusiness sector's digital transformation has boosted food production, processing, waste management, grain storage, warehouse management, and marketing of agricultural products, helping to address important economic issues like food insecurity, poverty, and unemployment in the majority of developing nations. [39, 40, 17]

In order to feed the population, create jobs, and maintain economic stability for many centuries, agriculture is a vital industry that has been the foundation of human civilization (Rehmani, 2025) [19]. Due to issues like climate change, poor soils, faulty supply chains, and a lack of sufficient funding, the agricultural sector is still a major source of concern today (Pretty *et al*., 2018). These are a few of the problems that negatively affect stability and production, thus coming up with creative solutions is essential. The process of bringing entrepreneurial skills to agriculture in order to promote innovation, productivity, and sustainability is known as agri-preneurship (Gupta *et al*., 2021). Young people have taken the lead in fostering innovation in the modern world by implementing innovative business strategies that would increase agricultural productivity (Iskander, 2021). The creativity, funding, and governmental regulations that will be employed to establish new agriculturally based businesses are referred to as agri-preneurship. According to Sharma *et al*. (2022), agri-preneurship is centered on commercial profitability, expansion and innovation, and the application of contemporary technologies, whereas conventional farming uses traditional methods and primarily focuses on subsistence farming. Climate smart agriculture, blockchain supply chain solutions, AI, and precision agriculture are a few of the solutions used in this industry to improve farming (Wolfert *et al*., 2017). In order to promote greater food production, sustainable production practices, and the growth of a thriving rural economy, agri-preneurship is therefore crucial (Rahman *et al*., 2022).

The sector has been undergoing transformation in recent years, which has resulted in the spread of various mobile-based services and applications. According to recent research on digitalization by the Technical Centre for Agriculture and Rural Cooperation (Digitalization of African Agriculture, 2019), as of 2019, digital apps reached 33 million smallholder farmers, with the number expected to rise to 200 million by 2030. These applications are varied and focus on supply chain management, market connections, financial access, and advisory and information services, which are the most popular (Digitalization of African Agriculture, 2019). El Bilali & Allahyari (2018) claim that by improving connectivity and expanding access to timely and accurate agricultural information, ICT-based

innovations can empower smallholder farmers in developing nations and improve rural livelihoods. For instance, to enhance access to extension services and market information, Esoko, a technological platform used in the majority of African nations, combines web and mobile services. In addition to giving farmers access to real-time weather and extension guidance, this lowers the expenses associated with market research.

Current developments include cutting-edge ICTs like blockchain, artificial intelligence, cloud computing, Internet of Things (IoT), computer, radio, television, and mobile phones, as well as big data analytics (OECD, 2017). El Bilali and Allahyari (2018) contend that by boosting productivity and improving traceability and transparency, these disruptive ICT developments have the potential to support agricultural sustainability transitions. According to Iliyas (2014), agricultural productivity can be raised through the employment of satellite technologies and geographical information systems for remote sensing. Furthermore, according to Wolfert *et al*. (2017), Ahoa *et al*. (2020), and Kassahun *et al*. (2020), big data analytics can be utilized to rethink business processes, drive real-time operational choices, and offer predictive insights in farming operations. Several technologies, including the Global Positioning System (GPS), Geographic Information Systems (GIS), mobile computing, sophisticated information processing, and software, are used in precision agriculture to provide detailed information on production variability in time and space (Zhang *et al*., 2002; Koksal & Tekinerdogan, 2019; Verdouw *et al*., 2019). Since ICT is known to play a major role in the expansion and advancement of agriculture, its use has drawn more attention in many developing nations in recent years.

This integrated literature review analyzes the scope, advantages, and disadvantages of digital and agritech, especially blockchain and IoT, in strengthening the supply chain resilience in Sub-Saharan Africa. It aims to achieve the following goals:

1. Outline the role of digital technology and Agritech innovations in the SSA food supply chains.
2. Determine resilience impacts derived from the outcome of transparency, traceability, market integration, and loss minimization.
3. Examine the adoption challenges and potential for policy, stakeholder, and public–private collaborations.
4. Analyze the data to formulate policy recommendations to aid in the governance and the targeted intervention through research, investment, and policy aimed at strengthening equitable and resilient food systems.

2. Literature Review

1. Digitalization, ICT and Smallholder Agriculture in SSA

The increasing use of digital technologies, known as "digitalization," is rapidly altering many facets of the economy, including agriculture (Choruma *et al*., 2024) [6]. Digitalization is transforming the agricultural sector by increasing food production's sustainability, efficiency, and productivity [1, 2]. By providing farmers with access to real-time weather, market prices, and agricultural extension services, digital technologies in the global north enhance decision-making at the farm level. For instance, robots are employed in Germany to milk cattle, saving time and labor (Langer & Kühl, 2023), while unmanned aerial vehicles (UAVs) are utilized in China to detect weeds and enable their early eradication (Wang *et al*., 2022). Sub-Saharan Africa (SSA), on the other hand, has not seen the same advancements in the digitalization of agriculture and continues to trail behind in the use of digital technology in this sector [3]. In Sub-Saharan Africa (SSA), where a significant portion of the workforce is employed in agriculture (Shimeles *et al*., 2018), digitalization presents chances to address some of the issues faced by smallholder producers [4, 5]. About 80% of SSA's agricultural labor force is made up of smallholder farmers, who also generate 90% of the food in the region [6]. However, a lot of smallholder farmers face significant obstacles, such as insufficient network coverage, expensive internet charges, limited access to loans, poor agricultural extension services, and limited access to market and weather information [7, 8]. Although SSA is seeing an increase in interest in digital agriculture, little is known about the kinds of digital technology farmers are utilizing and the difficulties they have when implementing them [9–11]. In addition to having little understanding of and expertise with properly using digital technologies, many smallholder farmers in the area still require assistance to purchase necessary digital instruments like laptops and smartphones [9, 12]. The digital divide and its effects on smallholder farmers need to be better understood [14], while adoption and usage rates of digital technology in agriculture are still low [13]. According to Shenglin *et al*. (2022), the term "digital divide" describes the unequal distribution of access to digital technologies, such as laptops, tablets, smartphones, and the Internet.

2. Blockchain, Iot &Supply Chain Resilience

Supply chain management, which integrates factors including information flow, storage and logistics, investments, and the exchange of goods and services, is essential in tackling issues of public health and food poverty. Creating cooperative relationships between producers, sellers, suppliers, and customers guarantees dynamic and effective operations. The automated systems that have emerged in modern supply chains offer several advantages, including lower costs and increased operational effectiveness. Leveraging technological improvements to improve quality control and minimize losses, especially in terms of health and safety, is a key component of agriculture and food supply chain management (Ellahi *et al*., 2024) [9]. Walmart's successful Blockchain trial for the supply of pork in China and IBM's food tracking software serve as examples of the use of blockchain technology in FSCs [18]. Examples of the increasing push for using blockchain technology into FSCs include Albertsons' 2019 admission to the IBM Food Trust network, which already includes Walmart and Carrefour [19]. The food industry is at the forefront of implementing cutting-edge efforts that use blockchains to improve supply chains, and FSCs have been key players in investigating this distributed ledger technology, providing a solution for the effective administration of supply chain operations [20–22]. The use of blockchain technology in the agri-food industry has attracted a lot of study interest lately, with an emphasis on improving supply chain efficiency, transparency, and food safety. In their investigation of blockchain's application in agriculture, Bermeo *et al*. [23] highlighted how it may enhance food safety and transaction times while also pointing out that there is a growing interest in blockchain's

application in food supply chains, especially in the Asian research community.

3. Smart Farming & Agritech Adoption

In agriculture, smart farming technology has emerged as the key to a game-changing innovation. Smart farming is the use of advanced technologies to traditional farming methods, propelled by the Fourth Industrial Revolution (IR 4.0), which promises a much more productive, sustainable, and efficient agricultural environment (Zhahir *et al*., 2024) [25]. Today's world is changing so quickly that the agriculture industry is expected to undergo a significant transformation and promise to meet the difficulties that come up [6]. Notwithstanding this ever-changing landscape, there has been a surge in smart farming research and innovation across several agricultural and technological fields [7–10]. The technology's potential is being intensively investigated by stakeholders at all levels. As a result, knowing what influences the adoption of technology is crucial since it provides insightful information about both the good and negative variables. Developing and utilizing technology to revolutionize it and move toward digital transformation is one strategy to enhance the agriculture industry. One agricultural technology product that can assist producers in improving the efficiency, quantifiability, and integration of their work is smart farming. The Internet of Things (IoT), artificial intelligence (AI), information technology (IT), and electrical devices are all components of smart farming approaches that will accurately measure farming conditions in terms of time, energy, and harvesting.

4. Enabling Ecosystems & Policy Perspectives

The Millennium Ecosystem Assessment is a widely recognized body of work that was created with input from more than 1300 scientists over the course of the last 20 years due to the increasing interest and volume of research into providing an ecosystem services framework to conservation policy (MEA, 2005). The discovery that 15 of the 24 ecosystem services examined were declining globally was arguably the most talked-about result of the MEA. Given their connection to human well-being, this decline is concerning and ought to serve as a basis for additional research evaluating how their provisioning has changed (Cook *et al*., 2017) [7]. The scientific community must (a) explicitly define ecological services and (b) categorize them for use in valuation, according to Fisher *et al*. (2009). The ecological features that will be included in a preferred classification scheme must be defined and understood in a clear yet practical manner in order to satisfy component (a). According to MEA (2005) and Kumar (2010), a preliminary comprehension of the specific ecological context and characteristic phenomena that characterize a study location is also necessary for an adequate classification of ecosystem services. biodiverse environments with rare or unusual forms of flora (flora, ferns, fungi, and mosses), fauna (particularly migratory bird species), genetic materials (enzymes frequently used as amplifiers of DNA fragments in forensics), algae (used in biomass and biofuels production), bacteria (used in industrial applications for biodegradation), and various microbes (helping to slow water flows and acting as waste management agents by reducing concentrations of toxins and heavy metals that spread to the wider environment). An intricate system comprising investors, government agencies, research institutes, incubators, and accelerators that assist early-stage businesses is known as a startup ecosystem (Mulas *et al*., 2017). The agriculture industry depends heavily on innovation and technology, as well as on access to funding and professional guidance through nascent startup ecosystems (Goyal *et al*., 2022). Previous research indicates that robust and encouraging entrepreneurial environments can promote the creation of Agri-tech companies and allow the commercialization of agricultural inventions (Reardon *et al*., 2021).

Although reviews highlight the theoretical advantages of blockchain, IoT, mobile ICT, as well as Agritech startups, very few studies integrate resilience outcomes in SSA food systems considering climate shocks, conflict, or supply chain disruption. Furthermore, there are no comprehensive reviews that focus on the narrative blending digital innovation, startup activity, FinTech automation, policy governance, and resilience. Your systematic review has the potential to address this gap by:

Armed with SSA food chains, you are tasked to map the digital and Agritech deployment.

Linking resilience dimensions (traceability, loss prevention, adaptive capacity) with system shocks.

Assess enablers/barriers (e.g. infrastructural, financial, policy, literacy) and Formulate integrated recommendations aimed at decision-makers, ecosystem architects, and innovators.

The thing of this scoping assessment is to present a thorough analysis of the variables affecting glitch startups and digital invention in enhancing the adaptability of the food force chain in Sub-Saharan Africa. The ideal of this study is to determine the crucial external factors affecting the relinquishment process by examining the literature from a variety of sources published between 2010 and 2024. This review acts as a foundation by methodically examining the literature and establishing the frame for further study in this area. This is how the study is set up. Section 2 list down the following literatures reviews. Section 3 provides a detailed description of the process. Section 4 also contains the analysis and discussion. The study is eventually concluded in Section 5

3. Research Method

To find, assess, and examine pertinent research on the influence of digital innovation and Agritech startups on food supply chain resilience in Sub-Saharan Africa, this study, "The Role of Digital Innovation and Agritech Startups in Strengthening Food Supply Chain Resilience in Sub-Saharan Africa," employed a systematic literature review (SLR). Research that specifically examined Agritech and the food supply chain had to be published in peer-reviewed journals indexed by either Copernicus, Scopus, or Sinta 2 to qualify for inclusion. The exclusion criteria included books,

editorials, opinion articles, and research that were not written in English.

The procedure of choosing the literature began with compiling the titles and abstracts that were discovered using the search strategy. One step in the initial screening process was reading abstracts to eliminate papers that had nothing to do with the research question. The articles that passed this stage proceeded to the full-text evaluation, where the inclusion and exclusion criteria were strictly adhered to. Two reviewers assessed the papers separately to reduce bias. We talked about any disagreements or, if necessary, sought a third reviewer. In the final stage, the focus shifted to gathering in-depth insights from selected studies that explore how digital innovation and Agritech startups are shaping the resilience of food supply chains in Sub-Saharan Africa. This involved analyzing each study's research design, participant profiles, methods of analysis, core findings, and overall conclusions. By following this systematic and evidence-driven approach, the research builds a well-rounded and insightful perspective on how new technologies and emerging agricultural businesses are strengthening supply chain stability. With food security becoming a growing concern, the role of digital transformation and innovation in agriculture is proving to be vital in promoting resilience and long-term sustainability within regional food systems. This research looks into how digital innovation and Agritech startups are helping make food supply chains more resilient in Sub-Saharan Africa. It takes a close look at the latest tech developments and startup activities in agriculture to understand how they help reduce risks and improve supply chain operations. The study also highlights what's missing in current strategies and offers ideas for making food systems stronger using digital tools that are both sustainable and easy to scale.

This was achieved by sourcing and analyzing 100 publications from the Web of Science index and Google Scholar, which amounts to 70 scientific journals. Additionally, 55 papers were eliminated from a follow-up full-text review because of factors like inadequate relevance to the research topic. After careful review, 15 peer-reviewed papers were found to meet all inclusion requirements. Content analysis and bibliometric analysis were carried out using the R packages CiteSpace (6.3.R1 Basic), Bibliometrix (version: 4.3.5), and Biblioshiny.

4. Results and Discussion

This research performs a systematic literature review on publications dating from 2020 to 2025 to examine how digital innovation and Agritech startups bolster the resiliency of food supply chains in Sub-Saharan Africa. Following an SLR approach, the review gathered and scrutinized publications pertaining to the role of technological and entrepreneurial innovations in alleviating supply chain agricultural concerns. The comprehensive review aims to reset the understanding of the region's emerging digital strategical options and their consequences on the sustainability and adaptability of the food systems.

A preliminary search yielded 100 articles using certain keywords. After titles and abstracts were screened, 70 articles were removed because they did not meet inclusion criteria. In a subsequent full-text review, 55 more papers were excluded due to factors such a lack of empirical data, non-peer review status, or insufficient relevance to the research objective. 15 peer-reviewed publications that satisfied all inclusion criteria were identified following a thorough study.

Table 1: 15 Articles Inclusive

S. No	Author's Name	Year	Research Title	Research Design	Sample	Method	Main Finding	Conclusion
1	(Rehmani, 2025) [19]	2025	Fostering Agri-preneurship: Exploring the Role of Startup Ecosystems in Transforming Agricultural Innovation and Sustainability	Exploratory Design	Agri-tech startup founders, ecosystem stakeholders (e.g., incubators, policy actors)	Case Study	Startup ecosystems, including funding, mentorship, and policy support, are vital for agri-preneurship to innovate in smart farming	Strengthening agri-preneurship through well-structured startup ecosystems can drive long-term agricultural sustainability and innovation
2	(Xinyan *et al*., 2024) [24]	2024	A Systematic Review of the Application of Blockchain Technology in Agricultural Supply Chain	Study of Literature	158 scientific publications were selected and subsequently analyzed	PRISMA approach Utilized software tools like RefWorks and Covidence	Blockchain significantly enhances traceability	blockchain is promising but faces adoption barriers; future research should target scalability, technology integration, and policy frameworks
3	(Smidt & Jokonya, 2022) [21]	2022	Factors affecting digital technology adoption by small-scale farmers in agriculture value chains (AVCs) in South Africa	Study of Literature	36 scientific publications were selected and subsequently analyzed	Literature Analysis	Identified economic, political, social, and governance factors affecting digital adoption	Highlights institutional support and tailored frameworks; calls for empirical follow-up work
4	(Vol *et al*., 2025) [23]	2025	Agricultural Sector Transformation Through A Systematic Literature Review	Study of Literature	30 – 100 scientific publications were selected and subsequently	Literature Analysis	Innovations in agriculture (e.g., digital tech, precision farming)	policy alignment, investment in tech, and collaborative research to support future

			(SLR) Approach: Innovations, Challenges and Future Opportunities		analyzed			transformation.
5	(Arthur *et al*., 2024) [1]	20204	Digital innovations: Implications for African agribusinesses	Bibliometric Analysis	47 scientific publications were selected and subsequently analyzed	PRISMA approach Utilized software tools like VOS viewer and R-Package-Bibliometrix	Digital agribusiness innovations in South, West, and North African countries	Digital innovations have been significant in Africa but are skewed towards certain regions.
6	(Mwewa *et al*., 2025) [15]	2025	Blockchain Technology: Improving Agricultural Supply Chain Efficiency and Transparency – A Review	Study of Literature	IoT/smart contracts in SSA context Literature Articles	Literature Analysis	Improves traceability, efficiency, pricing fairness, data credibility.	Blockchain can transform SSA's supply chains if scalable solutions and enabling policies are developed.
7	(Choruma *et al*., 2024) [6]	2024	Digitalization in agriculture: A scoping review of technologies in practice, challenges, and opportunities for smallholder farmers in sub-Saharan Africa	Study of Literature	27 scientific publications were selected and subsequently analyzed	Literature Analysis	Digital technologies offer opportunities for improving access to information and markets, and enhancing productivity	Digitalization offers transformative possibilities for smallholder farmers and can contributing to the growth of agriculture in SSA.
8	(Kudama *et al*., 2021) [12]	2021	Will digital solution transform Sub-Sahara African agriculture?	Study of Literature	60 recent empirical academic studies conducted on impacts on digital solution in the region.	Empirical analysis	Digital solutions have enabled smallholder farmers in SSA to access timely information, financial transactions, and empowerment benefits.	SSA countries should invest in adaptable technologies, ensure equal involvement, and provide affordable access and training to fully benefit from digitalization.
9	(Oyeyemi, 2022) [16]	2022	Artificial Intelligence in Agricultural Supply Chains: Lessons from the US for Nigeria	Study of Literature	Existing peer-reviewed studies on AI in Agri-supply chains from the US & Nigeria.	Literature Analysis	AI has significantly improved agricultural performance and efficiency in the US by enhancing productivity and reducing digital literacy, and emphasizes the need for a coordinated approach to successfully implement AI in Nigeria.	Nigeria's agricultural sector, its success hinges on a coordinated approach involving government, academia, the private sector, and international partners.
10	(Jellason *et al*., 2021) [10]	2021	Agriculture 4.0: Is Sub-Saharan Africa Ready?	Perspective Analysis	Not mentioned (the paper does not specify a sample size or demographic details of a sample group	Experimental Approach	Technologies can help smallholder farmers in SSA improve production and incomes by diversifying and enhancing their systems.	SSA faces in embracing agriculture 4.0 technologies and the risks associated with not adopting these technologies but promote agroecology principles.
11	(Balasundram *et al*., 2023) [3]	2023	The Role of Digital Agriculture in Mitigating Climate Change and	Study of Literature	Existing peer-reviewed studies on Digital farming	Literature Analysis	Technological and food consumption-based measures are identified as key	Digital agriculture technologies can improve efficiency across the agri-

			Ensuring Food Security: An Overview		technologies (e.g., IoT, precision agriculture)		strategies for reducing greenhouse gas emissions and improving food security.	food sector, reducing environmental impact.
12	(Maria Gulzar *et al*., 2020)	2020	Climate Smart Agriculture: A Survey and Taxonomy.	Study of Literature	30 scientific publications were selected focused on CSA & Small Farms	Literature Analysis	The use of advanced technologies like IoT, AI, and Big Data analytics in SA and CSA for optimizing crop health and food safety.	Smart Agriculture (SA) and Climate Smart Agriculture (CSA) to mitigate climate change impacts on food security.
13	(Kuteyi & Winkler, 2022) [13]	2022	Logistics Challenges in Sub-Saharan Africa and Opportunities for Digitalization	Study of Literature	287 scientific publications were selected and Semi-structured interviews: 6 logistics service providers and professionals.	Literature Analysis	Eliminating logistics bottlenecks can reduce monopolies and increase supplier participation, while digital technologies can improve speed, efficiency,	Digitalization has the potential to facilitate growth and development by improving logistics performance.
14	(Borjas *et al*., 2023) [5]	2023	Digital transformation as a contributor of efficiency and resilience in the agri-food supply chain: A literature review	Study of Literature	31 scientific publications were selected and subsequently analyzed	Qualitative approach	The implementation of technologies like Blockchain, IoT, and AI enhances visibility and process optimization.	Resilience is crucial for continuous food supply and is an important factor in technology implementation.
15	(Seppelt *et al*., 2020) [20]	2020	Deciphering the Biodiversity-Production Mutualism in the Global Food Security Debate.	Conceptual analytical	Existing peer-reviewed studies on Global Food Security Debate	Literature Analysis	A comprehensive framework is proposed to understand the biodiversity-production mutualism, highlighting biodiversity's importance in ecosystem functions.	Champion agroecological policies and integrate biodiversity into agroecological economic frameworks while focusing on sustainable intensification in developing countries.

After reviewing the titles and abstracts, we identified 70 out of the first 100 papers identified via keyword search that were disqualified as irrelevant for the predetermined inclusion criteria. During the full-text review, we removed an additional 55 papers due to a lack of empirical evidence, non-peer-reviewed reviews, and insufficient relevance to the study's main objective. In total, we retained fifteen peer-reviewed articles for further analysis. These articles help build an understanding of the role of Agritech companies and digital innovations in strengthening the resilience of food supply chains in sub-Saharan Africa.

The findings of this study have significant policy ramifications for encouraging the efficient application of digital technologies in SSA's smallholder agricultural systems. First, it is critical to address the issue of smallholder farmers' low levels of digital literacy. To improve farmers' digital literacy and abilities, policy interventions should offer training courses and capacity-building projects [9, 21]. This could involve community-based programs like farmer field schools, extension services, and training workshops to ensure smallholder farmers have the skills they need to use digital tools effectively. To ensure that these interventions are responsive to the true needs and preferences of the target community, it is crucial to emphasize that they should involve bottom-up engagement (Banda *et al*., 2020; Makhado *et al*., 2021). Farm mechanization has transformed food production globally, allowing it to keep up with population expansion, with the exception of a few less industrialized nations, particularly those in sub-Saharan Africa, which is lagging behind in the use of robots and automation. To proceed to the following phases of mechanization, some bottlenecks must be removed(Paparas & Harper, 2020).

Effective digitalization requires the establishment of the fundamental infrastructure necessary to support it. 600 million people in Sub-Saharan Africa, for instance, lack access to power, and the region's electrification rate is still only around 46.75% as of 2021 [36]. In nations like Nigeria, Ethiopia, Tanzania, Uganda, and the Democratic Republic of the Congo, over half of the population is underserved, and electrification rates are still extremely low. Therefore, when basic electricity is unavailable, pursuing digital transformation is highly impracticable. In this way, a push for digitization would be a misalignment of goals. The digitization of supply chain activities systems, including registration, financial payments, clearance and forwarding, and so forth, will greatly reduce excessive bureaucracy, increase efficiency and transparency, and make it easier for investors to enter the market. Automating processes and systems can save up to 108 hours required for export border

compliance in the region, which is around three and seven times higher than in emerging and developed economies, respectively [3] (p. 18). This will result in speedier processing times.

The food industry has seen a variety of business models emerge as a result of a confluence of opportunities made possible by advancements in technology(Bernardi & Azucar, 2020). In fact, as the needs of consumers have evolved throughout time, market participants have attempted to fill the gaps left by these new developments (The European House – Ambrosetti, 2019). Food on Demand, also known as Just-in-Time Online Delivery, is the first type of business model to develop. As sustainability has gained more attention, new methods of food production, distribution, and consumption have been developed with the goal of reducing the length of the food supply chain (De Bernardi, Bertello, & Venuti, 2020; Murdoch, Marsden, & Banks, 2000; Renting, Marsden, & Banks, 2003). According to De Bernardi, Bertello, and Venuti (2019), organizations have been forced to take a systematic approach in order to pursue sustainable development. This includes collaborating with different subjects throughout their value chain, from suppliers to ultimate consumers.

Based on decentralized, autonomous, community-focused, and sustainable business models, food systems have challenged the traditional food system, which is defined by a centralized, reliant, competitive, and dominant nature (Blay-Palmer *et al*., 2018). The food value chain now revolves around the fundamental ideas of social embeddedness, trust, transparency, and unity (Hendrickson & Heffernan, 2002; Kirwan, 2004). According to De Bernardi, Bertello, and Venuti (2019), Food Assembly is a new digital platform for food that is founded on the idea of the short food supply chain. Although most SSA countries have adopted aquaculture, the region now produces barely 1% of the world's farmed fish. Its glacial pace over the past few decades has thwarted efforts by governments, private sector investors, and internal development organizations. But in the long run, aquaculture's huge potential is still universally recognized as crucial to addressing the region's nutrition and food security issues. There are still obstacles to overcome, but in several nations, things seem to be getting better. Growth has been positive in many areas, especially when combined with the expansion of better farming methods and infrastructure. The private sector has been able to drive aquaculture development thanks to appropriate government legislation, which has led to the establishment and intensification of small and medium-sized businesses as well as market-driven and large-scale commercial projects.

Important Thematic Results

The chosen literature identified a number of recurring themes about the function of agritech startups and digital innovation:

A. Technology-Driven Supply Chain Efficiency

Technology is the use of information in a specific and repeatable manner to achieve practical objectives [6]. Emphasized how innovations such as blockchain, IoT tools, and mobile-based platforms improve management of data, tracking of inventory, and logistics in real-time. These tools reduce the worrying issues of spoilage, delays and asymmetries in information markets in the vulnerable food systems of Sub-Saharan Africa while increasing transparency.

Through more prosperity, enhanced comfort and quality of life, and advancements in medicine, it has boosted human wellbeing. In addition, technology can lead to social disadvantages like technological unemployment or adverse effects like pollution or resource depletion [6]. Numerous articles discuss various aspects of technology, such as its history, hand tools, economic development, societal developments, engineering procedures, and artificial intelligence (AI) [7]. AI technology can be applied in computer science, biology, and other domains and has had significant societal effects [8]. To increase productivity and cut expenses, the apparel manufacturing sector has embraced a number of technologies(Khan *et al*., 2023). These include customized production runs, rapid data analytics, supply chain enhancements, machine learning, and 3D capabilities. Digital textile printing has also made it possible to produce distinctive custom designs quickly and affordably [15].

B. Market Access and Farmer Empowerment

For farmers to increase their income, improve their well-being, and lessen poverty, they must participate in the market. It enhances livelihoods and makes access to larger markets possible. It is crucial to examine the effects of market participation in order to develop policies that guarantee fair benefits, encourage sustainable growth, and solve the difficulties farmers encounter when trying to access and profit from markets (Ma *et al*., 2024). Farmers must choose the best marketing channel since it affects their ability to access markets, their income through price realization, and how cost-effective it is to reach customers. The right channel has a direct impact on their livelihood and financial stability by expanding their market reach, increasing their profitability, and bolstering the sustainability of their farming operations. The farmer must determine how to meet these consumption needs during the harvest season each year, when household grain production is realized, as well as during the "lean" period that occurs in between successive grain harvests due to the seasonal nature of agricultural production (Negede, 2023; Stephens *et al*., 2011). The number of farmers or the amount of their produce sold in the market can be used to assess the density of market participation(Tanko *et al*., 2023).

C. Early Warning and Climate Adaptation

The capacity of short-term weather forecasts, including both deterministic and probabilistic forecasts, to predict the weather with a lead time of one or two weeks has significantly increased over the past 40 years (Bauer *et al*., 2015). Worldwide, EWS have saved lives by using these weather forecasts to warn people. For instance, Golnaraghi (2012) cited seven instances of effective EWS for hydrological and meteorological threats, ranging from weather warning systems in Germany to tropical cyclones in Cuba. Early warning systems for famine have facilitated the mobilization of humanitarian aid in advance (Funk *et al*., 2019), demonstrating the importance of impact-based forecasting that incorporates meteorological and seasonal climate predictions to provide prompt and efficient responses. According to Perera *et al*. (2019), the implementation of flood early warning systems worldwide has contributed to a decrease in the number of fatalities during flood disasters. The cost-benefit ratio of Europe's flood early warning system investment has actually been 400 to 1, according to Pappenberger *et al*. (2015). Disaster

consequences have been lessened and property and livelihoods have been safeguarded through the implementation of early warning systems.(Coughlan de Perez *et al*., 2022) Examples include flood forecasting in Bangladesh (Fakhruddin 2014) and early flood response in West Africa by the Red Cross (Braman *et al*., 2008). EWS has grown to be a significant climate change adaptation strategy in nations all over the world, as demonstrated by these and other examples. In response to the increasing frequency and severity of extreme events, EWS has become increasingly important. However, considering the catastrophic events of today, relatively small-scale EWS in many locations fail to sufficiently mobilize action (Lumbroso *et al*., 2016, REAP, 2022). In response, EWS investments have been suggested by scientists, politicians, and humanitarians as a way to adapt to climate change. The Sendai Framework for Disaster Risk Reduction has suggested EWS as a way to meet its goals (Zia and Wagner, 2015). One billion more people should be covered by new or improved EWS by 2025, according to goals set by the Risk-Informed Early Action Partnership, which was established in 2019 (Wilkinson *et al*., 2020, REAP, 2022).

D. Financing and Inclusion Through Digital Channels

Policymakers and academics are currently debating the importance of digital finance and financial inclusion for economic growth in depth. Digital finance is the term used to describe the financial services that banks and non-banking financial institutions provide to their clients by connecting digital channels such as cards, the internet, and mobile phones with safe digital payment systems (Gomber, Koch, & Siering, 2017). Adoption of digital finance can solve the problems that still affect people, companies, governments, and economies. Financial inclusion is being impacted and increased by digitization, which also has a number of positive effects on banking performance over the long run, lowers financial costs for financial institutions and Fintech providers, and offers convenient and secure financial services. Since SMEs are unable to locate goods and services that meet their demands and commercial requirements, the policies are regrettably unchanged for them (Rasheed & Siddiqui, 2018; Rasmussen, 2018). The needs of financial institutions are described as being low in scale and high in complexity. In addition, providing financial services to SMEs typically results in higher costs for the supplier as well as smaller revenue streams. It is evident that when the government and policymakers are deficient in one area, the other side will see an improvement in the way different rules and regulations are implemented(Rasheed *et al*., 2019).

5. Conclusion

The consequences of this first analysis underscore the need to adopt digital technologies alongside Agritech companies to reinforce the food supply chain in Sub-Saharan Africa. The studies being evaluated showcase the need to factor in the views of all relevant participants in the smallholder inclusive and scalable digital agriculture solution development to include: consumer, legislator, Agritech entrepreneur, and smallholder farmer. Furthermore, building local stakeholders' capacity, assigning responsible monitoring and evaluation bodies for implementing agencies, and impact dissemination through digital channels fosters trust. Aside from serving as tools for enhancing operational efficiency, the stakeholders' digital platforms provide avenues for real-time monitoring of agricultural activities and their environmental impacts. Agribusinesses can effectively align their strategies with resilience targets using digital innovation in the four key areas: knowledge/technology transfer, internal process optimization, farmer/customer satisfaction, and profitability. Risk exposure, costs, and access to credit and insurance are improved with the use of digital tools. Enhanced decisional power and supply chain trust among farmers and customers are improved through digital platforms. From a business perspective, digital solutions simplify tasks such as market access, pest control, and logistics. From a learning and innovation perspective, they also foster novel Agri-entrepreneurial activities and the upskilling of rural communities.

As the findings of the study illustrate, Agritech companies and digital innovation are vital for bolstering agricultural supply chains in resilience and efficiency for sub-Saharan Africa. These technologies are often linked to better economic outcomes and food security due to improved market access, reduced post-harvest losses, and optimal resource utilization. Enhanced market access for agricultural goods and greater food security is often the outcome of improved market access, reduced post-harvest losses, and optimal resource utilization. To fully embrace these technologies, investment in digital infrastructure, a culture of learning, strong-backed institutions, and precise application of data mining to monitor supply chain performance for advanced analytics are indispensable for successful integration. The author of the study highlighted the efficacy of Agritech solutions for SMEs and smallholder farmers, given the reduced operational costs, real-time data provision, and accelerated logistics, increasing the agility and responsiveness of operations. Increased productivity and service delivery in areas such as horticulture and dairy, as well as grains, demonstrate that both crop and livestock value chains enjoy these benefits. The study does have some constraints, focusing on literature from 2020 to 2025, a shortage of generalizable case studies and pilot program coverage, as well as uneven representation from certain countries and farming divisions.

In conclusion still, the effects of Agritech startup companies and innovation in the digital sphere have, with agility, transformed the food supply chain in the Sub-Saharan region of Africa. As noted, the impact is substantial, but the long-term resilience of the supply chain is deeply intertwined with collaboration, supportive policies, and regional infrastructure. Expanding these results will require studying more agro-ecological zones and spanning wider timeframes.

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