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FOOD SECURITY: THE ROLE OF DIGITAL TECHNOLOGY IN NIGERIA'S AGRICULTURAL DEVELOPMENT

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Abstract
Food security in Nigeria faces mounting threats from climate change, insecurity, infrastructural deficits, and rapid population growth. Although agriculture contributes significantly to the economy, systemic inefficiencies and socio-economic inequalities continue to limit productivity, particularly among smallholder (small scale) farmers. This paper examines the role of digital technology in transforming Nigeria's agricultural sector to address these challenges and enhance food security. Drawing on recent innovations such as artificial intelligence (AI), Internet of Things (IoT), and mobile-based platforms, the study explores how digital tools are being integrated into the agricultural value chain, from crop production and soil monitoring to storage, distribution, and market access. It presents case studies of agritech initiatives like Hello Tractor and Crop2Cash and evaluates policy frameworks such as NAVSA and the National Agricultural Technology and Innovation Policy. The paper highlights the potential of digital agriculture to reduce post-harvest losses, improve input efficiency, empower rural populations, and mitigate risks posed by climate and conflict. It concludes by calling for inclusive policies, rural infrastructure development, and targeted digital literacy programs to ensure that technology adoption is both equitable and impactful. Ultimately, digital innovation is positioned as a strategic pathway toward food security, economic empowerment, and national stability in Nigeria.

Keywords: Agritech, Food Security, Agriculture, Artificial Intelligence (AI), Farmers, Agripreneur, Digital Technology, Nigeria.

Introduction
Agriculture remains a vital sector in Nigeria, contributing approximately 24% to the national Gross Domestic Product (GDP) and employing nearly 40% of the workforce (FAO, 2023). It is a primary source of livelihood for much of the rural population and plays a pivotal role in food provision, poverty alleviation, and economic diversification. However, despite its importance, the sector is plagued by systemic structural deficiencies that continue to hinder its productivity and sustainability. These include limited access to mechanization, poor extension services, underfunded agricultural research systems, and a persistent reliance on rain-fed cultivation. Most Nigerian farmers operate at a smallholder (small scale) level, with minimal access to credit, quality inputs, insurance, and reliable markets. Additional inefficiencies such as inadequate storage, poor transportation infrastructure, erratic electricity supply, and weak value chain integration—further constrain the sector's capacity to meet rising domestic food demand.

Climate-related pressures have exacerbated these challenges. Erratic rainfall, desertification, prolonged droughts, and increased flooding have disrupted planting cycles and depleted soil quality, particularly in northern Nigeria (World Bank, 2020). These environmental threats have been accompanied by worsening rural insecurity. Ongoing conflicts between herders and farmers, armed banditry, and insurgencies in the northeast have led to massive displacement, farm abandonment, and restricted access to farmland. These conditions have severely affected food production and distribution, increasing inflation and contributing to heightened food insecurity.

Compounding these issues is Nigeria's rapidly growing population, which now exceeds 221 million and is projected to surpass 400 million by 2050 (UN DESA, 2022). With an annual growth rate of 2.6%, demand for food, water, and land is intensifying at an unsustainable pace. In July 2023, the Nigerian government declared a national emergency on food insecurity, warning that over 26 million people could experience acute hunger by mid-2024 as a result of climate shocks, violent conflict and systemic breakdowns in food production and supply (FEWS NET, 2023). The threat is not only a humanitarian crisis but also a growing challenge to national development, stability, and public health.

Amidst these intersecting crises, digital technology offers new and scalable solutions to modernize Nigeria's agricultural systems and address food insecurity. Technologies such as Artificial Intelligence (AI), the Internet of Things (IoT), mobile applications (Apps), blockchain, and remote sensing have demonstrated potential to revolutionize every phase of the agricultural value chain. These tools facilitate more accurate weather forecasting, improve pest and disease monitoring, enable precision irrigation, reduce post-harvest losses and improve smallholder farmers' access to markets, inputs, and financial services. When appropriately deployed, digital solutions can help bridge the rural-urban divide and make agriculture more inclusive, sustainable and profitable.

This research is motivated by the need to critically examine how digital technology can be systematically leveraged to enhance food security in Nigeria. The study is guided by four key objectives: first, to analyze the prevailing food security challenges and the underlying causes of agricultural underperformance; second, to assess the effectiveness of digital technologies particularly AI, IoT, and mobile platforms in boosting productivity and market access; third, to examine how agritech innovations are being adopted by smallholder farmers and other rural stakeholders; and fourth, to evaluate the institutional and policy frameworks that enable or hinder the integration of digital solutions in Nigerian agriculture.

To achieve these aims, the study addresses the following research questions: What are the structural, environmental, and socio-economic drivers of food insecurity in Nigeria? How are digital technologies currently being applied to improve agricultural performance and food system resilience? What opportunities and constraints shape

the adoption of digital tools among smallholder farmers? And finally, how effective are Nigeria's policies and institutions in fostering inclusive, technology-driven agricultural transformation?

In exploring these questions, the study seeks to contribute to scholarly and policy debates on digital agriculture and to propose actionable strategies for a resilient, equitable and food-secure Nigeria in the digital era.

Methodology

The interest of this research paper emerged from ongoing observations and reflective inquiry into the intersection of food security, agricultural development and the integration of digital technology in Nigeria. The approach employed is qualitative in nature and relies exclusively on secondary data sources. The foundational data for this study was obtained through comprehensive desktop research, which involved the systematic review of open-access academic articles, institutional reports, policy documents and peer-reviewed literature related to agritech innovation, digital transformation, food systems, and agricultural policies in Nigeria and other comparable developing economies.

Sources reviewed include publications from international organizations such as the Food and Agriculture Organization (FAO), World Bank, International Food Policy Research Institute (IFPRI), and various Nigerian government ministries and agencies. These materials provided the conceptual framework and empirical context necessary for analyzing the role of digital technologies in agricultural development and food security. The study focused on thematic areas including the digital divide, smart farming tools, policy alignment, institutional readiness, and inclusive innovation.

Particular attention was paid to literature that documented case studies of agritech platforms like Hello Tractor, Crop2Cash and Farmcrowdy, as well as national policies such as the National Agricultural Technology and Innovation Policy (NATIP) and the Nigeria Digital Economy Strategy. These case-specific insights were synthesized to identify patterns, challenges, and emerging opportunities across the agricultural value chain.

There were limitations associated with relying solely on secondary data. These include potential gaps in the availability of up-to-date local data, reliance on published sources that may not fully capture on-the-ground realities, and constraints in triangulating multiple perspectives that primary data could have offered. Nonetheless, the scope and quality of the reviewed literature provided a sufficiently broad and credible basis for the study's conclusions and recommendations.

Statement of the Problem

Despite its vast agricultural potential, Nigeria faces persistent food insecurity, with over 26 million people projected to experience acute hunger in 2024—especially in

rural areas. Structural challenges such as low productivity, outdated farming methods, poor infrastructure, and limited access to credit and inputs continue to hamper the sector. These problems are worsened by climate change, environmental degradation and insecurity, which have disrupted agricultural activities and livelihoods.

Traditional farming systems are no longer sufficient to meet the demands of a rapidly growing population, projected to exceed 400 million by 2050. While digital technologies offer promising solutions—such as data analytics, climate-smart tools and improved market access—their adoption remains uneven and limited due to infrastructural and literacy barriers. Many smallholder farmers lack access to essential digital resources, and national strategies often fail to address localized needs.

This study responds to the critical need to explore how digital technologies can be systematically and inclusively leveraged to strengthen food security in Nigeria. It focuses on identifying existing innovations, policy frameworks and the enabling conditions necessary to bridge the digital divide and transform agricultural development.

Literature Review

Food security in Nigeria is a complex challenge shaped by structural, environmental, and socio-economic factors. Despite its vast agricultural potential and a predominantly agrarian population, Nigeria continues to experience high levels of hunger and undernourishment. Food production has struggled to keep pace with rapid population growth, exacerbated by climate shocks, rural insecurity, and systemic inefficiencies in input supply and distribution networks (World Bank, 2020; FEWS NET, 2023). In northern Nigeria, insecurity and displacement caused by insurgency and conflict have drastically reduced farming activities, further aggravating food scarcity (UNHCR, 2022). These conditions highlight the need for transformative interventions that enhance resilience and productivity across the food system.

Globally, digital agriculture has emerged as a strategic solution to modern agricultural challenges. Defined as the use of technologies such as Artificial Intelligence (AI), Internet of Things (IoT), blockchain, drones, and mobile platforms to optimize food production and distribution, digital agriculture enables precision farming, real-time data monitoring, and improved decision-making (Kamilaris et al., 2018). In developed countries, such tools have already revolutionized farming practices. For instance, in the United States and China, AI and big data analytics are used for crop monitoring, pest detection, and efficient resource allocation (OECD, 2021; Jin, Wu, & Zhang, 2022). These successes illustrate the potential of digital agriculture in improving food security and sustainability, particularly when supported by strong policy and infrastructure.

Across Sub-Saharan Africa, a growing number of digital agriculture initiatives have begun to demonstrate impact. Countries such as Kenya and Ghana have launched platforms like M-Farm, iCow and Esoko, which provide smallholder farmers with access to market information, weather forecasts and financial services via mobile technology (CTA, 2019; World Bank, 2020). These tools have helped to increase yields, improve access to markets and reduce post-harvest losses. In Nigeria, agritech innovations such as Hello Tractor, Crop2Cash, Farmcrowdy and Thrive Agric are making similar strides. These startups address key gaps in mechanization, input financing, and market access by using mobile apps and digital tools tailored to smallholder farmers' needs (Aker et al., 2021). However, challenges such as limited internet access, low digital literacy and affordability continue to hinder large-scale adoption, especially among rural women and youth (IFPRI, 2020).

Efforts to support digital agriculture in Nigeria are gaining momentum through national policies and institutional reforms. The National Agricultural Technology and Innovation Policy (NATIP 2021–2025) and the Nigeria Digital Economy Policy and Strategy (2020–2030) both identify agriculture as a priority sector for technological transformation. Additionally, the draft National Artificial Intelligence Strategy under development by NITDA reinforces the government's commitment to digital integration. Nevertheless, these policies often face implementation gaps, poor coordination and underfunding. Furthermore, gaps in the research highlight the need for gender-inclusive, interdisciplinary studies and robust monitoring mechanisms. Without addressing these foundational issues, the full potential of digital agriculture in securing Nigeria's food future will remain unrealized.

The Role of Technology in Agriculture

Digital technology has increasingly become central to agricultural innovation globally and in Nigeria. AI applications in agriculture include crop and soil monitoring, pest and disease detection, yield prediction and climate modeling (Kamilaris, Kartakoullis, & Prenafeta-Boldú, 2018). IoT devices help track weather conditions, soil nutrients and moisture levels in real-time, allowing farmers to make informed decisions on irrigation, fertilization and harvesting schedules. These technologies improve resource efficiency, reduce post-harvest losses and increase agricultural productivity.

In Nigeria, agritech startups such as Crop2Cash, Hello Tractor and Thrive Agric have begun deploying AI and digital tools to provide access to credit, machinery, and market information for smallholder farmers. For instance, Hello Tractor uses GPS-enabled smart tractors to connect farmers with tractor owners through a digital platform, enhancing access to mechanization (Aker, Ghosh, & Burrell, 2021). Similarly, Crop2Cash enables farmers to build financial profiles and access loans through mobile apps, addressing long-standing credit barriers.

Government-led initiatives like the National Adopted Village for Smart Agriculture (NAVSA) seek to create digital ecosystems in rural farming communities by providing

AI-supported devices, training and market linkages. The NAVSA program aligns with the broader objectives of the Nigeria Digital Agriculture Strategy (2021), which aims to digitize at least 10 million farmers by 2030.

Agritech Innovations and Initiatives

The growing ecosystem of Nigerian agritech solutions reflects the significant potential of digital tools in addressing food insecurity and transforming agricultural productivity. Platforms like Farmcrowdy enable individuals to invest directly in agriculture, thereby providing crucial capital for farmers who often lack access to traditional financing. SOSAI's MarketMap offers farmers real-time access to commodity prices and nearby buyers, enhancing market transparency and empowering farmers to negotiate better deals. In Plateau State, pilot studies using AI-based pest detection tools have demonstrated remarkable outcomes, including a 20% increase in crop yields and a 15% reduction in pesticide usage, highlighting the efficiency gains possible through digital innovation (AgriTech Nigeria, 2023).

Public-private partnerships play a critical role in driving the adoption and scaling of digital technologies. Collaborations between the Federal Ministry of Agriculture, international development organizations like the African Development Bank, and private sector actors have led to the establishment of Special Agro-Industrial Processing Zones (SAPZs). These zones are designed to modernize agricultural processing, enhance value addition, and improve market logistics. Through SAPZs, digital infrastructure such as logistics tracking systems, supply chain analytics, and digital payment platforms are being integrated, creating more efficient, transparent and resilient agricultural value chains. Additionally, initiatives focused on capacity building and digital literacy are helping smallholder farmers and agripreneurs leverage these technologies effectively, ensuring that digital transformation is inclusive and widespread.

Challenges to Food Security in Nigeria

Despite the promise of technology, Nigeria's agricultural sector remains vulnerable to several persistent challenges that hinder progress toward food security. Climate change is a primary concern. Increasing temperatures, prolonged droughts, and seasonal flooding have degraded arable land and disrupted farming calendars, reducing agricultural productivity and threatening livelihoods (IPCC, 2021). Smallholder farmers, who dominate the sector, are particularly exposed to these risks due to limited access to adaptive technologies and climate-resilient practices.

Infrastructural limitations further exacerbate food insecurity. Poor road networks, unreliable electricity and limited cold storage facilities lead to high post-harvest losses, especially in perishable crops such as fruits, vegetables and dairy products. According to the Nigerian Stored Products Research Institute (NSPRI), post-harvest losses can reach up to 40% annually, severely undermining farmers' incomes and

food availability. Additionally, insufficient irrigation infrastructure restricts year-round farming, making production heavily dependent on unpredictable rainfall.

Socio-economic inequalities also impede equitable access to digital tools. Women, who constitute nearly half of Nigeria's agricultural workforce, often face barriers in accessing land, credit and digital literacy training, limiting their ability to benefit from agritech innovations (IFPRI, 2020). Rural youth encounter systemic obstacles, including inadequate education, limited employment opportunities, and poor internet connectivity, which hinder technology adoption and agricultural entrepreneurship.

Security challenges, especially in the North-East and North-West regions, present a grave threat to food production. Armed conflicts, banditry, herder-farmer clashes and land encroachments have resulted in mass displacement, abandoned farms and disrupted supply chains, exacerbating food shortages and economic instability (UNHCR, 2022). These security concerns also discourage investment and the extension of digital infrastructure in vulnerable areas, further widening the rural-urban divide.

Digital Technology as a Strategic Solution

Digital agriculture offers scalable, innovative solutions to address the deep-rooted structural problems facing Nigeria's food systems. AI-driven platforms, for example, can forecast weather patterns with greater accuracy and recommend adaptive planting schedules, reducing farmers' vulnerability to climate variability and helping optimize resource use. In Tanzania, machine learning models used for early detection of common bean diseases have led to increased yields and higher farmer incomes, demonstrating the tangible benefits of such technologies (CTA, 2019).

Nigeria is beginning to replicate these successes through local and regional agritech initiatives. The Kitovu platform leverages AI to analyze soil data alongside crop requirements, enabling farmers to optimize fertilizer application, which improves crop health while reducing costs and environmental impact. Apollo Agriculture, although originally based in Kenya, is expanding its AI-driven micro-loan and advisory services into Nigeria. This platform provides low-income farmers with tailored financial products and farming advice, empowering them to make better production decisions and access credit without traditional collateral.

Inclusive adoption is crucial to ensuring these technologies reach Nigeria's diverse farming communities. Community-based digital literacy programs, often led by NGOs and research institutions, are vital in this regard. Many offer SMS- and USSD-based advisory services that work on basic mobile phones, overcoming barriers of limited smartphone and internet penetration. These services provide timely information on weather updates, pest control and market prices, significantly improving decision-making for resource-constrained farmers (Tambo, Wünscher, & Fischer, 2021). By

bridging the digital divide, such programs enable smallholders, women and rural youth to participate more fully in the digital agricultural economy, fostering inclusive growth and resilience. Additionally, ongoing efforts to improve rural connectivity and affordable internet access are key to expanding the reach and impact of these digital solutions across Nigeria's vast agricultural landscape.

Policy and Institutional Support

For digital technology to fully support Nigeria's food security goals, strong institutional backing and enabling policy frameworks are essential. The National Agricultural Technology and Innovation Policy (2021–2025) provides a comprehensive roadmap for integrating innovation into the agricultural sector. It emphasizes strengthening research and development, promoting digital skills training and ensuring inclusive access to finance, inputs, and markets for smallholder farmers and agripreneurs. Similarly, Nigeria's National Artificial Intelligence Strategy, currently being developed by the National Information Technology Development Agency (NITDA), aims to facilitate AI deployment across key sectors including agriculture, health and education, recognizing the transformative potential of AI to boost productivity and resilience.

To complement these policy efforts, significant investment in infrastructure is required. Expanding rural broadband networks and providing stable, affordable electricity are critical to enabling farmers to leverage digital tools effectively. The Rural Electrification Agency (REA) has made commendable progress in deploying off-grid solar mini-grids to remote farming communities, enabling refrigeration for perishables, mobile device charging and basic processing technologies. However, current coverage remains limited, and scaling these interventions is vital to reach Nigeria's vast rural population.

Public-private partnerships (PPPs) are increasingly important in operationalizing digital agriculture strategies. For instance, the Digital Agriculture Platform developed by NITDA in partnership with Microsoft offers smallholder farmers timely weather forecasts, pest alerts, and market price information through a user-friendly, multilingual mobile app. Such collaborations drive innovation while facilitating technology transfer and capacity building. National policy must continue fostering these innovation-friendly partnerships, with clear regulations to protect farmers' data privacy, promote transparency and ensure equitable access to digital services across gender and socio-economic divides. Institutional coordination between ministries, local governments, private sector actors, and civil society will be key to sustaining and scaling digital agriculture solutions.

Case Studies

Successful implementation of digital agriculture in other countries offers valuable lessons for Nigeria. In India, the e-Choupal initiative created a digital network that connected farmers directly to suppliers and markets, significantly improving

efficiency and reducing exploitation by intermediaries. Similarly, Kenya's M-Farm and iCow platforms have demonstrated how SMS-based services can deliver vital information to smallholder farmers in remote areas.

In the United States, precision farming technologies have become standard practice, enabling farmers to use GPS-guided machinery, satellite imagery and AI algorithms to optimize input use and maximize yields. Government support through subsidies and research programs has been key to this widespread adoption. Meanwhile, in China, the integration of AI, blockchain, and big data into agricultural planning has improved food traceability, safety standards and land-use efficiency (Jin, Wu, & Zhang, 2022).

In the Nigerian context, agritech platforms like Kitovu and Apollo Agriculture (originally based in Kenya) are beginning to introduce bundled services digital advisory, access to inputs and micro-loans, to underserved farming regions. These case studies underscore the importance of locally adapted models that align with the literacy levels, infrastructure conditions, and cultural practices of Nigerian farmers.

Future Directions

As Nigeria's population accelerates toward an estimated 400 million by 2050, the pressure on food systems will intensify. A forward-looking approach to food security must integrate digital innovation with climate-smart practices, inclusive policies and investment in human capital. Governments must commit to digital literacy training at scale, especially for women and rural youth, who are essential to agricultural labor and innovation.

Technological development must also be coupled with social safeguards. Issues such as data sovereignty, digital fraud and algorithmic bias need to be addressed through regulation and ethical standards. Furthermore, the development of local tech talent is crucial. Nigeria's universities and vocational institutions should incorporate agri-digital courses and support innovation incubators.

Environmental sustainability must remain a core principle. Technologies that enable resource-efficient practices such as drip irrigation, low-carbon transport, and renewable energy should be prioritized. Smart farming must also be resilient to conflict: developing tools that function offline or under low-connectivity conditions will ensure continuity in crisis zones.

Finally, international cooperation will be essential. Nigeria can benefit from knowledge exchange, research partnerships, and donor funding from multilateral agencies such as the FAO, World Bank and African Union. By aligning national strategies with global development goals, Nigeria can not only secure its own food future but contribute to broader regional stability.

Conclusion

The nexus between digital technology and food security has emerged as a critical frontier in Nigeria and the broader West African region. Given agriculture's pivotal role employing nearly 40% of Nigeria's labor force and contributing approximately 24% to its GDP as of 2023, the imperative to enhance food security amidst rapid population growth (exceeding 2.6% annually) cannot be overstated. Artificial Intelligence (AI) is increasingly recognized as a transformative force within this context, offering innovative approaches to longstanding agricultural challenges including climate variability, infrastructural deficits, and limited technological access.

This study underscores the multifaceted applications of AI ranging from predictive analytics and real-time crop monitoring to automated pest control that collectively hold potential to optimize productivity, streamline supply chains and reduce post-harvest losses. The ongoing efforts by Nigerian agritech startups and government-led programs to drive AI adoption are noteworthy, particularly their role in equipping smallholder farmers with critical digital competencies that can translate into enhanced productivity and income diversification. However, these advancements are not without significant constraints; infrastructural inadequacies, digital literacy gaps, and socio-economic inequities especially those affecting women, who constitute a substantial segment of the agricultural workforce remain major barriers to widespread and inclusive adoption.

Initiatives such as the National Adopted Village for Smart Agriculture (NAVSA) exemplify strategic attempts to integrate digital tools within agricultural governance frameworks, thereby addressing policy and implementation challenges. Crucially, this research highlights that the promise of AI-driven agriculture must be coupled with deliberate strategies to ensure equitable access and participation, emphasizing inclusivity as a cornerstone for sustainable impact.

Looking ahead, the realization of AI's full potential in Nigeria's agricultural sector is contingent upon consistent and reliable energy supply, robust rural digital infrastructure and comprehensive capacity-building interventions. Investments in rural electrification, broadband connectivity and enabling regulatory environments are imperative to cultivate an ecosystem conducive to digital agricultural innovation. Equally important is the need for synergistic collaboration among governmental agencies, private sector actors, development partners and local communities to scale and sustain these initiatives effectively.

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