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Role of Agri-Tech Innovations in Enhancing Agribusiness Adaptation to Food Insecurity in Nigeria (A Review)

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Abstract
This study examined the role of Agri-Tech innovations in strengthening agribusiness resilience to food insecurity in Nigeria. Food insecurity is a persistent problem, particularly for small-scale farmers and agribusinesses engaged in traditional farming methods. The present research considered some of the Agri-Tech interventions like digital agriculture, precision farming, financial technology, climate-smart technologies, and blockchain technology. Digital agriculture increased productivity through real-time access to extension services and market data, but low infrastructure and digital literacy prevented it from being adopted. Precision agriculture, through satellite imaging and drone technology, optimized resource use and increased crop yields. Financial technology instruments, such as digital credit facilities and mobile banking, increased access to finance for farmers, increasing investment in new ways of farming. Climate-smart technologies such as drought-resistant crop varieties and machine-driven irrigation mitigated the impact of climate change, while blockchain enhanced supply chain clarity and market effectiveness. Despite such innovations, poor infrastructure, low levels of digital literacy, and the high cost of implementation were some of the issues that constrained high-scale uptake. The study proposed strategic policy interventions, increased digital resource accessibility, and private sector alliances for scaling Agri-Tech solutions for enhanced food security and agribusiness resilience in Nigeria.

Keywords: Agri-Tech Innovations, Food Insecurity, Agribusiness Adaptation, Digital Agriculture, Precision Farming, Financial Technology (FinTech)

Introduction
Poverty and food insecurity remain cross-cutting issues in Nigeria especially within the smallholder farmers and Agri-food businesses that adopt conventional farming systems (Akinwale & Grobler, 2023). Nigeria's agricultural sector that employs over 70% of the Nigeria population has been faced with numerous challenges such as; Climate change Post harvest losses, low productivity, inadequate capital and limited access to modern technology in form of inputs (Mhlanga & Ndhlovu, 2023). Such challenges have deterred agribusinesses from delivering increasing food demands from the burgeoning Nigerian population, yet more triggering hunger and malnutrition (Uwoghiren, 2024).

Agricultural technological advancements or Agri-Tech have emerged as a game-changer to counter such challenges. Agri-Tech is a range of digital technologies and innovations used to increase farm productivity, including precision farming and AI-based analytics, as well as financial services and supply chains using blockchain (Abdulai *et al*., 2023). With the application of such technologies, agribusiness firms can nullify the adverse impacts of food insecurity, bring about enhanced productivity, and supply chain efficiency. Empirical evidence reveals farmers' embracement of agricultural services via online platforms greatly boosts farmers' involvement in agribusiness and consequently, technology plays a core part in food security sustenance (Degila *et al*., 2023).

Some of the most significant causes of food insecurity in Nigeria include climate change. Higher temperatures, reduced rainfall and frequent occurrences of climate related events such as storms, floods and droughts have negatively impacted yields, pest attacks and soil degradation (McCarthy *et al*., 2023).

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Smallholder farmers, as the pillar of Nigeria's agricultural economy, are unable to adjust to such climatic changes because of their financial constraints and information unavailability. However, Agri-Tech interventions such as remote sensing, climate-smart advisory, and data-informed decision-supporting systems provide a window of opportunity for building resilience against these challenges (Arthur *et al*., 2024). For instance, Bangladesh saw how farmers who were using climate-resilient technologies experienced costs of production being reduced and return on investment increased, thus emphasizing the need for the inclusion of technology in agriculture practice (Sunny, Lan & Islam, 2024).

Despite the potential of Agri-Tech innovations to aid food security, their application in Nigeria is minimal. Various challenges like poor internet connectivity, low literacy levels, high costs of technology, and unwillingness to adopt constrain them from being applied on a large scale (Mhlanga & Ndhlovu, 2023). Addressing these challenges requires concerted effort by the government, private sector, and research institutions to come up with policies for Agri-Tech adoption and provide economic incentives to agribusiness firms to embrace technological solutions (Bano & Hasnat, 2024).

This review explores the role of Agri-Tech innovations in boosting agribusiness resilience to food insecurity in Nigeria. It reviews some of the technological options provided to farmers, their food security contribution, and their constraint to mass adoption. This review, aided by empirical research and scholarly articles, reveals the potential for how Nigeria can use Agri-Tech innovations for sustainable food production and economic growth.

Conceptual Framework of Agri-Tech Innovations

Technological intervention in the agricultural sector can be referred to as an agri-tech solution or innovation that seeks to ensure that the agricultural system is efficient, productive and able to withstand all conditions. Agri-tech involves the use of information and communication technologies, precision agriculture strategies, and also financial technologies for decision making when there is risk, limited resources and enhanced agricultural business decision makings (Chukwugozie *et al*., 2025). Since food security remains an issue of concern, especially in Nigeria, there is a high likelihood of shift to a new solution in the use of agri technology as the panacea to offering smallholder farmers and agri-businesses tools that enables them to cope with uncertainties of the economy and the climate.

Agri-tech innovations can be classified into several major categories:

Digital Agriculture and Data-Driven Decision Making

Digital agriculture can therefore be defined as use of ICTs in agricultural systems with the view of enhancing on-farm decision making, improvement of utilization of resources in agriculture and increase production. Some of the most essential digital technologies include the mobile applications, cloud computing, artificial intelligence, and big data analysis. Through these technologies, a farmer gains the ability to access real time market information, check the status of the soil, have forecast on the weather, and even control the amount of inputs for farming (Abdulai *et al*., 2023).

Empirical studies have established that digitalization increases agricultural productivity and efficiency, particularly when it is underpinned by agricultural extension services that offer one-on-one guidance to farmers (Degila *et al*., 2023). For instance, Osagiede (2024a), highlighted the need for Africa's agriculture to embrace digital technologies to enhance farm productivity by informing the decision making and minimize post-harvest losses. Nonetheless, the implementation of digital agriculture faces constraints such as an unstable internet connection, inconsistent electricity supply, and illiteracy on the farmers especially in the rural area of Nigeria (Martins *et al*., 2024).

To address these constraints, governments and private players must invest in the development of digital infrastructure, improving internet penetration in rural regions, and instituting farmer training on digital literacy (Sunny, Lan & Islam, 2024). The development of localized and user-friendly mobile

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applications that provide information in local languages also has the potential to enhance accessibility and usability among smallholder farmers.

Precision Agriculture and Smart Farming

Precision farming is the use of advanced technologies such as satellite imagery, remote monitoring, and the Internet of Things (IoT) technologies in order to optimize the use of available resources and, farm output. Precision farming thus implements sensors, GPS in machinery, as well as AI analytics to help the farmers get the best value for their inputs, while reducing on wastage and enhancing the yield on their farms (Abate *et al*., 2023).

The use of drones is one of the most promising technologies in precision agriculture that include crops, irrigation, and pests. Abate *et al*. (2023) confirmed that future drone farming innovation enhance the decision making of smallholder farmers through gaining more precise knowledge on the health of crops and the status of the soils in real time. They were able to cut costs of input but increased on the output of their output in farming. The same applications can be used in Nigeria, because unfavourable climate variations and soil conditions bring down the yield in agriculture.

Irrigation systems with IoT-based sensors that regulate the application of water according to real-time soil moisture levels have also proved useful in optimizing water use efficiency and insulating agriculture from impacts of climate change (Sunny, Lan, & Islam, 2024). In Nigeria, where drought and unpredictable rainfall undercut agriculture outputs, the use of such technology can result in increased resiliency and sustainability in agriculture business. But the costliness of acquiring and holding precision farming tools is still a bottleneck to their wider uptake among smallholder farmers. Funding, subsidy, and sensitization on utilizing the technology can spur more usage and longer-term sustainable usage (Degila *et al*., 2023).

Financial and Market Technologies for Agricultural Growth

Financing access remains a key barrier to agribusiness development in Nigeria. FinTech innovations like mobile banking, online credit facilities, and blockchain-based payments present new channels of financing that can enable agribusinesses and farmers (Abdulai, Kc, & Fraser, 2023). Digital financial products, including mobile wallets and peer-to-peer lending platforms, enable smallholder farmers to access credit, purchase farm inputs, and invest in new agricultural technologies.

Jadoun (2023) demonstrated that FinTech usage among Bangladeshi farmers lowered costs of production significantly and enhanced return on investment. In Nigeria, the same tactic can bridge the financial inclusion gap by extending low-interest loans, crop insurance, and secure payment systems to smallholder farmers. However, digital finance remains constrained by inadequate digital literacy, access to mobile phones being low, and issues with cybersecurity (Uwoghiren, 2024).

Blockchain technology enhances transparency and confidence in agricultural deals by creating tamper-proof decentralized records of payment, contracts, and sales. Its application within Nigeria's agriculture can boost the management of the supply chain through reducing fraud, enhancing traceability, and providing ease of dealing between consumers, traders, and farmers (Abate *et al*., 2023). The combination of mobile payment platforms with blockchain can assist smallholder farmers in accessing market access at less cost and excluding intermediaries.

Furthermore, climate-smart technology, such as weather-indexed insurance and automated financial planning tools, helps farmers manage risks associated with climate variability. Osagiede (2024) emphasized that such innovations play a vital role in building resilience to food insecurity by ensuring financial stability in the event of environmental or economic shocks. Policymakers, however, must offer regulatory provisions for enabling financial inclusion, digital security, and farmer education on digital financial management in order for such technologies to reach scale.

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Food Insecurity in Nigeria: A Persistent Issue

Food insecurity remains a perennial problem in Nigeria and this has affected millions of families, especially the smallholder farmers and the rural dweller. There are a number of challenges experienced in Nigeria which today contribute to the occurrence of food insecurity some of them include climate change, inadequate infrastructure, low productivity in farming, post-harvest losses, ineffective markets and volatility in the economy. The Food and Agriculture Organization of the United Nations, FAO, report indicates that 19.4 million people in Nigeria were considered to be food insecure in 2022 due to conflict, recession and climate change shocks. It is also caused by high food costs and inflation whereby the prices of basic food stocks prove unreasonably high for the majority of households.

Climate Change and Environmental Degradation

Food insecurity in Nigeria can be attributed to climate change because of rainfall shocks which results in low productivity in times of drought or flood. It has been ascertained that increased temperatures together with volatile weather conditions reduce crop and animal yields hence the farmer cannot sustain food production (McCarthy *et al*., 2023). In rain-fed agriculture areas people also suffer from the climate change since the rain is not predictably leading to crops failure food shortage, and income loss. Also, desertification and soil erosion particularly in the northern part of Nigeria, limit the amount of arable land available, thereby contributing to food insecurity.

Low Agricultural Productivity and Post-Harvest Losses

Nigeria's agriculture is characterized by smallholder farmers who lack access to improved farming practices, quality inputs, and mechanization. The productivity levels, as such, are low and food supply is low. Abdulai *et al*. (2023) discovered that in spite of the digital agricultural services, most of the farmers are limited by having limited access to digital tools and the quality of extension services is poor, and this hinders them from adopting improved production practices. Post-harvest losses are also a major cause of food insecurity. Post-harvest losses are put at 30% to 50% of Nigeria's crop production as a result of poor storage, transportation, and processing facilities (Chukwugozie *et al*., 2025). In the absence of value addition and effective supply chains, huge quantities of food are lost even before they reach the consumers.

Economic Challenges and Market Inefficiencies

Nigeria's economic instability, which is characterized by currency devaluation, high inflation, and rising input costs, has had adverse effects on food security. The smallholder farmers cannot afford to buy quality seeds, fertilizers, and other inputs required, reducing their productivity and profitability. In addition, underdeveloped markets and road networks discourage farmers from transporting their produce to urban centers, thus leading to surpluses in rural and food shortages in urban centers (Degila *et al*., 2023). Price volatility also exacerbates the phenomenon because unpredictable market changes make it difficult for farmers to plan their production cycles and investment.

Insecurity and Conflict

Conflict in the North-East and North-West of the country has damaged both farming operations and the delivery routes of food supplies. The attacks on farming communities combined with rural population displacement and destroyed farms have caused decreased food production and market accessibility. The actions of insurgent groups and bandits have driven numerous farmers to leave their land behind which deepens the food shortage problem and raises the need for foreign food assistance (Bello, 2024). Aggressive conflicts between pastoralists and farmers who fight for their share of local water and land resources create a major risk to farm productivity.

Limited Access to Finance and Technology

Financial services accessibility stands as a principal impediment for Nigerian smallholder farmers because they cannot finance better agricultural technologies nor inputs. The authors Bahn, Yehya and

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Zurayk (2021) noted that farmer access restrictions to credit produce barriers to adopt modern farming techniques which supplies a continuous pattern of low productivity and food shortage. Farmer financial constraints grow worse because they take high-interest loans from informal lenders which limits their funding potential. Lack of digital tools coupled with insufficient internet connectivity prevents farmers from benefiting from modern agri-tech solutions for enhancing food production and market access (Uwoghiren, 2024).

Urbanization and Changing Consumption Patterns

The fast growth of urban areas in Nigeria resulted in raising food requirements which exceeded agriculture-based food supply capabilities. Metropolitan dwellers mostly consume refined and foreign food products that cost more money and remain out of reach for welfare-strapped families. The wage-based change in consumption preferences requires an expansion of native food output but leads to increasing import costs for food. Rapid urban demand for locally produced food exceeds supply levels therefore food insecurity persists to worsen which impacts both residents of cities and rural areas (McCarthy *et al.*, 2023).

Government Policies and Interventions

The Nigerian government uses three primary programs namely the Agricultural Transformation Agenda (ATA), the National Food Security Program, and the Anchor Borrowers' Programme (ABP) as tools to combat food insecurity. These agricultural programs attempt to improve food production but policy inconsistencies combined with corruption and insufficient budgetary support constrain their achievement (Abdulai *et al*., 2023). Additional interventions should target smallholder farmers while simultaneously focusing on infrastructure development as well as integrating agri-tech innovation to improve food security.

The Role of Agri-Tech Innovations in Agribusiness Adaptation

The adoption of agri-tech innovations by Nigerian agribusinesses represents a necessary solution for reducing the effects of food insecurity throughout the country. Modern society depends on technology-driven solutions because traditional farming practices remain unable to address challenges from climate change alongside resource scarcity (Sunday, 2024). Smallholder farmers and agribusinesses are witnessing a transformative effect through agri-tech solutions because of improved market connectivity along with better access to financial services and climate resilience approaches according to empirical research findings.

Digital Platforms and Market Access

Market access presents the biggest obstacle for agribusiness development throughout Nigeria. Smallholder farmers face numerous challenges when attempting to establish connections with buyers while handling price negotiations and dealing with supply chain inefficiencies. New digital platforms now serve as market revolutionaries because they let farmers access instant market information and enable direct sales without middlemen. The research by Abdulai *et al*. (2023) shows most Northern Ghana farmers use mobile phones or radios while noting the necessity of developing advanced solutions which unite digital systems. Mobile-based applications and digital marketplaces help increase market efficiency through better transaction clarity together with better price deals and reduced waste from harvested products according to Abate *et al*. (2023).

Nigerian platforms FarmCrowdy and AgroMall use mobile technology to create new market channels for farmers who gain expanded clients and lower financial expenses. The platforms offer farm advisory help which enables farmers to obtain appropriate guidance about their agricultural choices from planting through harvesting to selling stages. Mhlanga and Ndhlovu (2023) reported that digital literacy and internet access pose significant challenges to widespread adoption among rural communities. Public

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and private sector collaboration to resolve present market barriers will optimize digital market access capabilities.

Precision Agriculture and Smart Farming

Modern farming experiences a transformation due to precision agriculture which combines artificial intelligence (AI) with remote sensing and the Internet of Things (IoT) for optimized resource utilization and increased operational efficiency. Farmers can achieve improved decision-making using data insights for their operations of soil management and irrigation and fertilization and pest control. The research by McCarthy *et al*. (2023) revealed how drones enabled Malawian smallholder farmers to monitor their fields and manage diseases as well as reduce resource expenditure. The research results point to possibilities for agritech disruptions in Nigerian agribusiness since the inefficient farming systems and uncontrolled resource use keep affecting food safety across the country.

In Nigeria, start-ups such as Hello Tractor have introduced AI-powered mechanization services that offer farmers a chance to hire tractors through mobile platforms, increasing efficiency and reducing labour costs (Osagiede, 2024). Additionally, IoT sensor-enabled smart irrigation systems allow farmers to monitor soil moisture levels and regulate water application, preventing drought-induced yield losses. In agreement, Osagiede (2024a) also believe that the adoption of climate-smart technology significantly reduced the cost of production while maximizing return on investment (ROI) in Bangladesh, another attestation of precision agriculture potential in Nigeria.

Financial Technology (FinTech) and Credit Accessibility

Accessibility to financing, albeit, remains a strong barrier to the improvement of smallholder farmers and agribusiness in Nigeria. Smallholder farmers who cannot provide collateral or records of financial transactions cannot secure bank loans; hence, they invest in key agricultural inputs inadequately. Traditional financing has not been very friendly to the farmers and this has been solved for by FinTech solutions, offering credit, insurance, and payments for agriculture. According to the study conducted by Abdulai, Kc, and Fraser (2023), several factors that affected the farmers included the ownership of mobile phones, level of digital literacy and access to extension services. This underpins the need for a combination of financial literacy and technology to drive the uptake of the innovations.

One of the most significant breakthroughs in using blockchain technology in the agribusiness is the development of financial systems for obtaining credit and making transactions, as in the case of the AgriLedger. These solutions apply decentralised ledgers to facilitate transparency while avoiding fraud, and increasing availability of credit. Mobile operators such as Paga and OPay have especially also help increase financial inclusion especially among the farmers to enable them conduct their transactions and also access micro-loans without necessarily having to depend on the conventional banking system (Uwoghiren, 2024).

Climate Resilience Through Smart Technologies

Farmers in Nigeria are under the daily risk of climate change impacting their yields and food sources due to changes in rainfall patterns, decline in soil fertility, and proliferation of pests. Such continual changes can only be addressed by agri-tech solutions like climate smart advisories and predictive analytics to enable the farmers (Bano & Hasnat, 2024). Some of the examples of knowledge-based applications include: Events such as weather forecasting which give real time climate information that can help farmers to schedule the appropriate time for planting and harvesting.

Mhlanga and Ndhlovu (2023) suggest that farmers in Africa can experience significant challenges when adopting technologies in the agricultural sector owing to restraints such as resource constraints, lack of skills, and innovation resistance. Nevertheless, positive experiences of other countries in the use of climate-resilient technologies indicates that appropriate policies could help spur uptake in Nigeria. According to Sunny, Lan, and Islam (2024), policy interventions made a significant difference in the

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development of climate adaptation strategies for different geographical regions, emphasizing climate-smart farming.

In Nigeria, organizations like Nigerian Meteorological Agency (NiMet) have been used as sources of localized climate data for farmers. The integration of AI-driven analytics with indigenous knowledge systems could also improve the resilience since it combines farming practices that have been used for many years with current technologies.

Blockchain and Supply Chain Transparency

The agricultural supply chain in Nigeria can be characterised by inefficiencies, fraud, and lack of transparency resulting in losses and market distortions. Blockchain technology provides an effective solution to such issues with a visible record of transactions making the system more accountable and less susceptible to corrupt practices. According to Abdulai and others (2023), it is established that block-chain based systems enhance supply chain by providing reliability on the nature of farming produce and proper pricing.

For instance, IBM Food Trust has deployed the technology in global agricultural markets to track food from the farm to the consumer. If the same systems can be implemented here in Nigeria, it could help tackle some of issues as fake inputs, price fixing and late payments to farmers among others. An understanding of how blockchain technology can promote trust and efficiency in markets is important for building food security.

Challenges in Implementing Agri-Tech Innovations

However, there are challenges that have limited the adoption of agri-tech innovations as a solution to food insecurity in Nigeria. These are dominated by infrastructural limitations, lack of finances, technology limitations, and cultural and social factors that hinder the business of agribusinesses from adopting hi-tech solutions.

- **Digital Divide and Limited Internet Connectivity:** One of the key issues hindering the ability to provide and adopt agri-tech solutions in Nigeria is the question of connectivity. The poor, particularly the rural farmers who dominate the agricultural sector, still endure inadequate Internet connection to avail digital resources. In their view, Abdulai *et al*., (2023) pointed out that most of the smallholder farming population in Northern Ghana relies on rudimentary sources of information such as phones, radio, and television and little or no access to digital platforms like the internet. This is especially true for Nigeria's farmers where low broadband penetration, predominantly in rural areas, hinders them from accessing authoritative agricultural information, digital extension services, and e-commerce.
- **High Cost of Technology and Financial Constraints:** One of the primary challenges is the cost that farmers incur to acquire the equipment and technology such as drones, precision farming implements, or even some of the Blockchain solutions. Smallholder farming in Nigeria is characterized by low financial capacities, implying that most of these farmers cannot afford to purchase such costly technologies on their own. Degila *et al*. (2023) stated that financial factors influence farmers' uptake of digital agriculture services. Yet, this problem is compounded in Nigeria where both availability of credit for agriculture and cost of funds as reflected in high interest rates on loans deny farmers an opportunity to adopt new technologies that can help boost their production.
- **Limited Digital Literacy and Technical Skills:** This is the case because majority of farmers and agribusiness entrepreneurs have low levels of digital/technology literacy and are unable to successfully implement agri-tech solutions and products. Osagiede (2024) pointed out that lack of skills, capacity, and awareness are some of the challenges common with digital transformation for agriculture in Africa. Due to the lack of training as well as capacity

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development activities, farmers are unable to adopt technology into their farming practices limiting impact of digital solutions.

- **Weak Institutional and Policy Frameworks:** Frequently, there are no sufficiently enabling legal structures or guidelines for the advancement of agri-tech endeavors in the nation, which makes it difficult for agri-entrpreneurs and tech designers. There is no coherent policy environment to regulate current frontier technologies like artificial intelligence for agri-food analytics or blockchain for fluid supply chain management which hinders investment in the sector. This is compounded by ambiguities of rules of data privacy and protection, which add to the challenges of implementing digital farming solutions (Chukwugozie *et al*., 2025).
- **Resistance to Change and Socio-Cultural Barriers:** The study reveals that most of the farmers in Nigeria area still practice traditional practices hence, they are reluctant to adopt change. A significant proportion of the farmers is still not fully convinced about the benefits of adopting technology and still employ traditional practices. Abate *et al*. (2023) also documented a similar process in Malawi showing that farmers were reluctant to embrace drone technology for increasing yields in agriculture. This is due to the fact that the individuals involved need to be educated on the benefits of agri-tech solutions need to be undertaken whereby, a pilot project is used as an example.
- **Infrastructure Deficiencies:** Lack of basic infrastructure and amenities such as erratic power supply and unavailability or poor road networks also hamper the adaptation and application of emerging technologies in the agricultural sector. Several of the smart farming technologies depend on power, which is a problem since Nigeria does not have a stable power supply. Also, inadequate transport linkages hinder the ability of farmers to get to markets affecting their motivation to adopt superior technologies in crop farming.
- **Security Concerns and Cyber Risks:** The problems of confidentiality and cybersecurity experience growing as digital technologies become more integrated into agriculture. Platforms developed based on the blockchain and Artificial Intelligence technologies aggregates a larger amount of agricultural data, and their storage and usage can lead to privacy issues and misuse. In their research, McCarthy *et al*. (2023) stressed the need to regulate how farmer's data is protected and used.

Policy Recommendations and Future Directions

In order to maximize the use of agri-tech in improving the capacity of agribusiness to address food insecurity in Nigeria, it will require the collaborative efforts of all the stakeholders such as the policy makers, private investors, and research organizations. In turn, there will be need to address these structural challenges as well as advocate for and build support for policies that support sustainable adoption. The following policy implications and future development directions are considered:

- **Government Support and Investment in Agri-Tech:** Needless to say, it is incumbent upon the Nigerian government to act as a catalyst for the growth and utilization of agri-technology. To address the gap and include technology in farming, there is a need to invest more in utilizing internet services to reach farmers in the rural areas or bringing electricity to the agrarian communities (Abdulai *et al*., 2023). Moreover, direct subsidies and incentives with regards to the agri-tech start-ups can foster innovation, bringing advances in technologies within the accessible reach of the smallholder farmers. For example McCarthy *et al*., (2023) identified that Malawian farmers' drone adoption was promoted by government sponsorship pointing to the same call in Nigeria.
- **Capacity Building and Digital Literacy Programs:** Lack of adequate digital skills are an issue that continues to affect technology use in Nigerian based agribusiness (Mhlanga & Ndhlovu, 2023). It may also be necessary to offer training to the smallholder farmers, extension agents, and agribusiness managers in areas such as use of appropriate digital tools; financial

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technology; precision farming. In this case, Abdulai, Kc, and Fraser (2023) argued that, indeed, digital competencies play a key role in the uptake of digital agricultural services by farmers and called for the need to pursue ongoing learning and support interventions. It would be advisable to attract private partners to open centers where farmers can receive practical training in the use of mobile platforms, blockchain, and AI systems for farming decisions.

- **Public-Private Partnerships for Technology Scaling:** Looking at the progress made in other developing countries, it has been attributed to a tripartite effort of government agencies, the private sector, and development organisations. Some of these ideas include the recommendation to encourage private players in digital agriculture, financial services, and mechanization to increase business in rural areas. The literature shows that it is through NGOs and private-sector projects that most digital agricultural services are provided to smallholder farmers in Africa today (Abdulai *et al*., 2023). Through governments embracing strategic partnerships, it is possible to have models where different players such as technology firms, telecommunication firms, and agribusiness firms work together to come up with proper and sustainable solutions.
- **Financial Accessibility and Inclusion for Smallholder Farmers:** One of the key barriers to the adoption of agri-tech is the problem of restricted capital. Technologically advanced and efficient methods of financing like mobile banking, digital credit products, and block-chain based credit platforms, should be encouraged to support investments in efficient farming technology (Sunny *et al*., 2024). By embracing digitization, financial services might help farmers better access inputs, invest in mechanization, and purchase insurance products hence increasing food security (sectors/framed, 2023). The governments and financial institutions need to come up with fiscal measures to support low-interest digital products mainly making affordable micro financing suitable for agribusinesses.
- **Development of Affordable and Locally Adapted Technologies:** One of the challenges towards adoption of agri-tech innovations is high costs since majority of smallholder farmers are unable to afford the cost of the technologies (Osagiede, 2024). Emphasis should thus be placed on Innovation and research that focus on producing cheaper and localized technologies to meet the farmers' needs in Nigeria. For instance, some simple precision agriculture tools based on locally accessible sensors and basic mobile applications could be economical in contrast to sophisticated technologies. Therefore, blockchain applications in agricultural supply chains must incorporate a friendly human-interface for farmers who are not fully conversant with technology.
- **Strengthening Agricultural Data Systems and Advisory Services:** Good quality data on farming is vital in helping those in the business make good decisions. Weather data and records on soil and market trends can be compiled in easily accessible repositories, of which farmers can make use to counter climate fluctuations and market volatilities (Mhlanga & Ndhlovu, 2023). Through such facilities, such as Short Messaging Service (SMS), Interactive Voice Response (IVR), or through mobile applications for example, knowledge deficits can be addressed and farmers equipped with information on the subject. Government should, therefore, invest in data-enabling infrastructure and increase collaboration with meteorological departments, research organizations, and digital solution firms to develop data smart agriculture.
- **Strengthening Policies on Data Privacy and Cybersecurity:** However, the increasing adoption of digital agriculture raises issues around data privacy and cybersecurity which if not well handled will impact farmers negatively (Osagiede, 2024). Proper policies include governance of ethical bound of using agricultural data and creating transparency in financial digital transactions and preventing cyber fraud to small farming productions. Secondly,

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blockchain technology should be utilized in improving the security and transparency of agricultural data especially in supply chain and financial services.

- **Climate-Smart Policies for Sustainable Agri-Tech Adoption:** The implementation of climate-smart policies into agri-tech constructs can improve the resistance of the agro-sector from the effects of food insecurity. To ensure environmental sustainability, the government should offer incentives to agribusiness that embrace green technologies; for instance solar based irrigation, seed varieties that are resistant to climate change or even climate data systems enhanced by Artificial Intelligence (Jadoun, 2023). There is also the need to complement these policies with research and development for development of climate change resilient agriculture practices to enable the disclosed agribusinesses adapt to the changing climate conditions.

Conclusion

New technologies in agriculture could significantly contribute towards the alteration of the current undertakings on food insecurity in Nigeria. Through better market transparency, the effective use of resources, financial inclusion, and better preparedness for climate change, all of these technologies aim at making the world more sustainable and capable of feeding the world's growing population. However, current opportunities of agri-tech solutions need enabling policies, more investment and commitment from other key players. Issues such as low digital literacy, expensive technologies, and dearth of funds are other prevailing issues that will require intervention to facilitate diffusion of these innovations. Overall, it is understood that the development and implementation of proper policies would go a long way in helping Nigeria use agri-tech innovations to boost production, and food security.

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