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Empirical Drivers of Modern Technology Adoption among Farmers in Nigeria

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Abstract
This study explores the empirical drivers influencing the adoption of modern agricultural technologies among smallholder farmers in Nigeria, focusing on socioeconomic, infrastructural, and cultural factors. Despite the potential of advanced agricultural technologies to address food security challenges and promote sustainable farming practices, various barriers hinder their widespread adoption. These include limited access to credit, inadequate infrastructure, insufficient education, and resistance to change, particularly among older and less educated farmers. The study emphasizes the critical role of government, NGOs, and the private sector in creating an enabling environment for technology adoption through targeted policies, financial support, and infrastructure investments. Furthermore, it highlights the importance of tailoring technological solutions to Nigeria's diverse agroecological zones and local socio-cultural contexts to ensure effectiveness and uptake. Recommendations include enhancing extension services, increasing farmer awareness, improving access to affordable credit, and investing in rural infrastructure. ICT tools, such as mobile applications, are identified as valuable in bridging information gaps and supporting technology adoption. Addressing these barriers and adopting a holistic approach, Nigeria can foster inclusive agricultural development, enhance productivity, and improve food security, ultimately contributing to the United Nations Sustainable Development Goals. The study calls for continued collaboration between stakeholders to facilitate the scaling of agricultural innovations in Nigeria.

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1. Introduction

Modern technology adoption in agriculture has emerged as a critical factor in addressing global food security challenges and promoting sustainable agricultural practices. Modern technology and advanced farming systems offer transformative opportunities to enhance productivity, improve resource efficiency, and mitigate environmental impacts. Studies on technology adoption have underscored the potential for governments, farming associations, and technology vendors to drive the uptake of innovative tools, especially in regions facing food insecurity and underdeveloped agricultural systems (Duncan *et al*., 2021; Aubert *et al*., 2012) [28, 13]. However, farmers' limited acceptance and participation remain crucial barriers to realizing the full potential of these innovations. This challenge is particularly pronounced in developing countries like Nigeria, where socioeconomic and infrastructural constraints significantly influence farmers' behavioural intentions to adopt new technologies (Adeyemi *et al*., 2023; Umar, 2022) [4, 83].

Agriculture has historically been the backbone of Nigeria's economy, contributing significantly to employment, food security, and gross domestic product (GDP). Before the oil boom of the 1970s, the sector accounted for nearly 50% of government revenue and 65% of the GDP, employing over 70% of the labour force (Ojo & Baiyegunhi, 2023; FMARD, 2015) [65, 34].

Although its relative economic contribution has declined, agriculture still provides livelihoods for millions of Nigerians, constituting approximately 23.4% of the GDP as of 2021 (World Bank, 2021) [86]. Smallholder farmers, who represent a significant portion of the agricultural workforce, produce up to 70% of the food consumed in Nigeria (Rapsomanikis, 2015) [73]. Their productivity is critical to achieving the United Nations Sustainable Development Goals (SDGs), particularly goals related to hunger eradication, poverty reduction, and sustainable agricultural practices (Andati *et al*., 2023) [11].

The sector has faced significant challenges in recent years, including declining productivity, climate change, and over-reliance on traditional farming methods (Achukwu *et al*., 2023). To address these issues, Nigeria has implemented several agricultural reforms, including the Agricultural Transformation Agenda (ATA), which emphasizes the modernization of agriculture through digital technologies (FMARD, 2015) [34]. Integrating tools like mobile platforms, drone-assisted monitoring, and smart sensors have proven effective in other countries, such as Kenya, providing a model for increasing agricultural efficiency and resilience in Nigeria (Parlasca *et al*., 2022; Andati *et al*., 2023) [71, 11].

This study seeks to identify the empirical drivers influencing the adoption of modern agricultural technologies among Nigerian farmers. While extensive research has been conducted on the effects of technology adoption on crop yields, food security, and economic development, there is limited focus on the behavioural and socioeconomic factors that affect farmers' willingness to adopt these innovations (Balana & Oyeyemi, 2022; Adeagbo *et al*., 2023) [15, 2]. This research aims to fill this gap by exploring the interplay between farmer awareness, resource access, and socio-cultural dynamics in technology adoption.

Considering Nigeria's unique socioeconomic landscape, the study provides actionable insights for policymakers, agricultural stakeholders, and technology developers to design interventions that promote inclusive and sustainable agricultural growth. Ultimately, it aligns with regional and global policy objectives, such as the African Union's Agenda 2063 and the SDGs, to modernize agriculture, enhance food security, and drive economic diversification across Nigeria and the broader African continent (AUC and AUDA-NEPAD, 2020) [5].

2. Overview of Modern Agricultural Technologies

Modern agricultural technologies encompass a wide range of innovations designed to enhance farming practices' efficiency, sustainability, and productivity. These technologies can broadly be categorized into hardware-based (technology-as-object) tools, such as tractors, drones, and smart sensors, and process-based (technology-as-process) innovations, including improved seeds, precision farming, and digital platforms (Choi, 2009; Ainissyifa *et al*., 2018) [21, 6]. In developed nations, tools like robots, aerial imaging, and GPS-based systems are transforming farming into a highly efficient industry (USDA, 2021) [84]. Meanwhile, in developing countries like Nigeria, more straightforward but impactful technologies, such as hybrid seeds, irrigation methods, and agronomic tools, are more prevalent and tailored to the needs of smallholder farmers (Mwangi & Kariuki, 2015; Jain *et al*., 2009) [59, 38].

Adopting modern agricultural technologies offers many benefits, particularly for smallholder farmers, who form the backbone of Nigeria's agrarian economy. These technologies enhance farm efficiency, increase yields, and mitigate the adverse impacts of climate change. For instance, digital tools such as the International Institute of Tropical Agriculture (IITA) Herbicide Calculator and Akilimo agronomy advisory tool have significantly reduced weed management costs and improved fertilizer usage for cassava farmers in Nigeria. These innovations foster sustainable farming practices by optimizing water usage, improving soil management, and reducing environmental pollution (Mandal *et al*., 2022; Balana & Oyeyemi, 2022) [48, 15].

Moreover, digital extension technologies like SMS-based agricultural recommendations and mobile apps have emerged as pivotal solutions, bridging gaps in market access and credit information (Rodríguez *et al*., 2021; McCampbell *et al*., 2021) [74, 50]. Such advancements boost productivity and uplift rural livelihoods by increasing incomes and ensuring food security (Nyarkoa & Kozárib, 2021; Kumar *et al*., 2021) [63, 44].

Modern agricultural technologies hold transformative potential for Nigeria and Africa, fostering a shift from subsistence to market-oriented farming. Tools like precision agriculture, digital platforms, and smart sensors can drive large-scale agricultural productivity and sustainability. With over 70% of Nigeria's labour force engaged in farming, scaling these innovations is crucial for rural development and economic growth (World Bank, 2021) [86].

3. Contextual Factors Influencing Technology Adoption in Nigeria

A combination of geographic, socioeconomic, and cultural factors influences agricultural technology adoption in Nigeria. These contextual elements shape farmers' decisions and their ability to integrate innovative solutions into their farming practices.

a) Geographic and Climatic Conditions

Nigeria's diverse agroecological zones, ranging from arid regions in the north to humid tropical zones in the south, heavily influence technology adoption. Farmers in arid areas may prioritize technologies that conserve water or improve drought resistance, while those in tropical regions might focus on pest-resistant varieties (Manda *et al*., 2020) [47]. Climate variability, including frequent droughts and unpredictable rainfall, necessitates adaptive technologies, such as improved seeds and precision irrigation systems (Ngango & Hong, 2021) [60].

b) Socioeconomic Characteristics of Nigerian Farmers

The socioeconomic attributes of farmers play a significant role in technology adoption. Education levels often determine how well farmers can understand and apply new technologies. Studies show that formal education positively correlates with the adoption of improved inputs, as educated farmers are better equipped to process and utilize technical information (Ajewole, 2010; Mignouna *et al*., 2011) [7, 54].

Age also impacts adoption; younger farmers are more likely to take risks associated with new technologies, while older farmers may prefer traditional methods due to familiarity or perceived risks (Lai-Solarin *et al*., 2021) [45]. Additionally, gender dynamics affect technology uptake, with women often facing barriers such as limited access to credit and extension services (Mwangi & Kariuki, 2015) [59].

Access to affordable credit directly influences farmers'

ability to adopt costly technologies, as Simtowe *et al*. (2010) [77] demonstrated that credit availability boosted the adoption of improved groundnut varieties. Membership in cooperatives or farmers' associations also increases the likelihood of providing access to resources, shared knowledge, and collective bargaining (Manda *et al*., 2020; Anang *et al*., 2020) [47, 20].

c) Cultural and Traditional Practices

Cultural beliefs and traditional farming practices can either hinder or facilitate technology adoption. In some cases, farmers' reluctance to deviate from ancestral practices slows the adoption of innovations. Amadu *et al*. (2020) [9] and Bell *et al*. (2018) [18] note that perceptions of the utility and compatibility of a technology with existing practices heavily influence its acceptance.

Social networks and peer influence also play a critical role. Beaman *et al*. (2018) [17] found that farmers who are part of strong social networks are more likely to adopt new technologies due to shared experiences and recommendations. Farmer-to-farmer extension methods have proven effective in promoting awareness and adoption of conservation agriculture (Fisher *et al*., 2018) [33].

d) Demographic Factors

Demographic influences, such as age, education, and income, shape adoption patterns. Michels *et al*. (2020) [53] observed that younger farmers with higher educational attainment and larger farms were more likely to use smartphone applications for agricultural purposes.

e) Policy-Driven Adoption

Policy interventions play a significant role in addressing cost-related barriers. Government initiatives to subsidize technology costs have proven effective in increasing adoption rates, as Okoroji (2019) [66] and Mandi and Patnaik (2019) [49] highlighted. These modern technology adoption among farmers in Nigeria reveals a complex interplay of socioeconomic, demographic, and policy-related factors. Further studies should continue to analyze these elements to devise targeted interventions that promote equitable technology diffusion.

4. Empirical Drivers of Technology Adoption

Adopting modern agricultural technology is influenced by various economic, institutional, social, and technological factors. Drawing from recent and relevant literature, the following subsections detail these drivers:

4.1 Economic Drivers

a) Access to Credit and Funding

Financial constraints are among the most critical barriers to technology adoption. Studies highlight the importance of accessible and affordable credit for smallholder farmers to invest in new technologies (Diagne, 2009; Awotide *et al*., 2015; Akrofi *et al*., 2019) [24, 14, 8]. For instance, off-farm income often serves as an alternative financial source, enabling households to adopt improved maize varieties with greater intensity (Diiro, 2013) [26]. Moreover, financial support helps mitigate risks associated with new technologies and secures fallback options in case of failure (Oyinbo *et al*., 2019) [70].

b) Cost of Technology and Affordability

The high cost of acquiring and maintaining agricultural technologies has hindered adoption. Lower-cost solutions or financial subsidies can significantly boost uptake (Mudhara *et al*., 2003; Fisher & Carr, 2015) [56, 32].

c) Market Demand and Profitability

Farmers are more likely to adopt technologies demonstrating a clear pathway to increased productivity, market access, and profitability. Accessibility to markets and financial returns strongly influence adoption decisions (Brown *et al*., 2019) [19].

4.2 Institutional Drivers

a) Government Policies and Subsidies

Policies that promote specific technologies often supported by training and subsidies, accelerate adoption rates (Tran *et al*., 2019) [81]. Infrastructure development, such as roads and irrigation, is critical in technology adoption (Kassie *et al*., 2015) [41].

b) Extension Services

Access to agricultural extension services is pivotal in informing farmers about the benefits of modern technology. Studies reveal a positive correlation between extension services and adoption rates, as extension agents facilitate knowledge transfer (Adejuwon, 2018; Oyinbo *et al*., 2019) [3, 70].

c) Cooperatives and Farmer Organizations

Membership in cooperatives and farmer organizations enhances social capital and provides platforms for technology dissemination, training, and resource pooling (Makate *et al*., 2019; Walisinghe *et al*., 2017) [46, 85].

4.3 Social and Cultural Drivers

a) Peer Influence and Community Networks

Social networks play a significant role in spreading awareness and encouraging adoption. Community networks facilitate technology diffusion through shared experiences and localized demonstrations (Conley & Udry, 2010; Bandiera & Rasul, 2006) [23, 16].

b) Gender Dynamics in Farming Households

Gender differences in resource access and decision-making power impact technology adoption. Studies show men generally adopt technology faster than women, though female-headed households adopt more readily when farm size is more significant (Murage *et al*., 2015; Fisher & Carr, 2015) [58, 32].

c) Education and Awareness Levels

Education positively influences adoption by improving farmers' cognitive ability to understand and evaluate new technologies. Educated farmers are more likely to adopt innovations (Hoang, 2020; Oyinbo *et al*., 2019) [36, 70]. Awareness campaigns that demonstrate the benefits and usability of new technologies also enhance adoption (Shang *et al*., 2020) [76].

4.4 Technological Factors

a) Perceived Ease of Use and Usefulness

Technologies perceived as easy to use and beneficial are more readily adopted. Adoption rates are higher for technologies with clear and demonstrable advantages, such as improved productivity or reduced labour requirements

(Shang *et al*., 2020) [76].

b) Compatibility with Existing Practices

Farmers prefer technologies that align with their existing agricultural practices and resource availability. Compatibility minimizes disruption and ensures smoother transitions (Roussy *et al*., 2015) [75].

c) Reliability and Performance of the Technology

Proven reliability and consistent performance build farmer trust in new technologies. Technologies that fail to meet expectations or yield inconsistent results are less likely to be adopted (Minten & Barrett, 2008; Duflo *et al*., 2006) [55, 27]. The adoption of modern agricultural technology among farmers in Nigeria is shaped by these factors, which ultimately drive agrarian transformation in Nigeria.

5. Barriers to Technology Adoption

The adoption of modern technology among farmers in Nigeria is hindered by various factors that can be grouped into three key areas: limited infrastructure, inadequate training and technical support, resistance to change and risk aversion.

a) Limited Infrastructure

Farmers in Nigeria face challenges related to infrastructure deficiencies, which significantly impede the adoption of advanced agricultural technologies. For instance, lack of reliable electricity, poor transportation networks, and limited access to irrigation systems constrain the implementation and efficiency of modern tools and methods (Klerkx *et al*., 2022; Mwangi & Kariuki, 2015) [42, 59]. Without the necessary infrastructure to support these technologies, their benefits remain inaccessible to many farmers. Additionally, the cost and availability of agricultural inputs like fertilizers, improved seeds, and machinery are further restricted by inadequate infrastructure, compounding the problem (Obisesan, 2014; Mukasa, 2018) [64, 57].

b) Inadequate Training and Technical Support

The complexity of agricultural technologies often poses a significant challenge to farmers, particularly those with low literacy levels (Oyetoro, 2022) [69]. Farmers often lack the necessary training to understand and use these innovations effectively. According to Kafando, Pelenguei, and Gnedeka (2022) [40], education plays a pivotal role in enabling farmers to adopt new technologies, as it enhances their ability to process complex information and apply it in practice. Unfortunately, extension services that should bridge this gap are often insufficient or ineffective due to inadequate funding, limited outreach, and poor communication channels (Adeyemi *et al*., 2023) [4].

Moreover, the top-down nature of technology transfer processes, which frequently exclude farmers from the development and implementation stages, exacerbates the disconnect between innovation and practical application (Oyetoro, 2022) [69]. Late delivery of technological inputs also diminishes their effectiveness, further discouraging adoption.

c) Resistance to Change and Risk Aversion

Many smallholder farmers in Nigeria are risk-averse and cautious about adopting new technologies due to uncertainty regarding their outcomes (Oni *et al*., 2017; Ramsey *et al*., 2016) [68, 72]. Factors such as high production risks, financial constraints, and fear of crop failure contribute to this resistance (Mukasa, 2018) [57]. Farmers often prioritize survival and stability over potential gains, adhering to traditional methods that they perceive as less risky. This mindset is further influenced by socio-cultural norms, which may discourage using specific innovations if they conflict with traditional practices (Oyetoro, 2022) [69].

Economic factors such as low income (Mwangi & Kariuki, 2015) [59], inadequate credit facilities, and limited market access also restrict farmers' ability to invest in new technologies (Obisesan, 2014) [64]. Furthermore, the lack of awareness and exposure to the benefits of modern tools, coupled with the absence of affordable and farmer-friendly digital solutions, continues to hinder technology adoption (Mhlanga & Ndhlovu, 2023; Krell *et al*., 2021) [52, 43].

6. Case Studies and Empirical Evidence on Technology Adoption among Farmers in Nigeria

6.1 The Role of ICT Tools in Enhancing Agricultural Practices

ICT tools have demonstrated transformative potential for Nigerian farmers. Studies like Haruna *et al*. (2018) [35] have highlighted how mobile phones facilitate the dissemination of agricultural information, leading to improved technology adoption and production outcomes. The findings are corroborated by Cole and Fernando (2016) [22], who established a direct link between mobile information delivery and technology uptake. These tools offer farmers access to critical updates on crop cultivation, weather, and market prices.

a) Impact of Mobile Applications in Agriculture

Okoroji *et al*. (2021) [67] revealed that mobile apps are becoming pivotal for disseminating farming knowledge, such as seed selection, pesticide use, and weather forecasts. The ease of use and relevance of these applications, as discussed by Diaz *et al*. (2021) [25], have been critical in enhancing farmers' willingness to adopt them, provided perceived costs are minimized.

b) Effect of ICT Based Extension Services on Technology Uptake

Studies emphasize the significant role of extension workers in encouraging new technology adoption (Ntshangase *et al*., 2018; Jumbe & Nyambose, 2016) [62, 39]. Farmers receiving regular guidance are likelier to embrace innovations like precision agriculture (PA) technologies, which require integrated diagnostic tools (GPS, GIS, and remote sensing) and applicative solutions (Chawade *et al*., 2019; Zhao *et al*., 2020) [20, 87].

6.2 Comparative Analysis of Adoption Rates by Location (Regional and Urban Classification)

a) Northern vs. Southern Nigeria

Differences in adoption rates can be attributed to socioeconomic disparities, access to extension services, and infrastructural variations. Access to credit and land tenure have significantly influenced the adoption of Natural Resource Management (NRM) technologies in Nigeria's northern regions, where larger farms dominate (Teklewold *et al*., 2013; Kassie *et al*., 2015) [79, 41]. Conversely, southern areas often benefit from smaller-scale, community-driven adoption models.

b) Rural vs. Urban Contexts

Despite their cost-conscious nature, rural farmers tend to embrace technologies when extension workers actively engage with them (Arslan *et al*., 2014) [12]. Urban and peri-urban farmers, on the other hand, often leverage ICTs, such as mobile apps, for producing marketing and networking, as evidenced by Krell *et al*. (2021) [43] and Thar *et al*. (2021) [80].

7. Role of Stakeholders in Technology Adoption among Nigerian Farmers

In adopting modern agricultural technologies, the involvement of diverse stakeholders is crucial for creating an environment conducive to innovation and facilitating widespread implementation. These stakeholders include the government, NGOs, and the private sector, each of which is vital in driving the adoption process.

a) Government's Role

The Nigerian government is central in supporting agricultural technology adoption through policy formulation, subsidies, and infrastructure provision. Government agencies such as the National Agricultural Research Institutes (NARIs) and state-based Agricultural Development Programs (ADPs) are instrumental in research, technology dissemination, and providing extension services to farmers (Mgbenka & Mbah, 2016) [51]. The Federal Ministry of Agriculture and Rural Development (2022) emphasizes strengthening agricultural research and training systems to collaborate more effectively with the private sector to develop localized technologies. Additionally, public sector programs facilitate farmers' access to essential tools and information, increasing their ability to adopt improved agricultural practices.

b) NGOs' Contribution

NGOs often work alongside the government to promote agricultural technologies, especially in underserved rural areas. They help by training, fostering awareness, and advocating for sustainable farming practices. These organizations also work on issues such as capacity building for farmers, creating better access to technology, and ensuring the sustainability of agricultural practices (Farm Square, 2022) [30].

c) Private Sector Involvement

The private sector contributes through technology development, production, and distribution. Private companies, especially those in seed distribution, play a vital role in making improved seeds available to farmers. However, the profitability of seed distribution remains a challenge due to high interest rates and the high cost of seeds compared to those provided by public sector programs (Ishiak *et al*., 2021) [37]. This has led to a slow adoption of technology in the private sector. Some companies like Premier Seeds and UAC Seed Division (Zaria-based) are organized, while others are small-scale, community-based enterprises. Despite these challenges, the private sector's involvement in technology dissemination is crucial to ensuring farmers have access to high-quality inputs.

7.1 Importance of Partnerships and Collaborations

The effectiveness of technology adoption in Nigerian agriculture depends significantly on the collaboration among the government, NGOs, and private sector. Partnerships create synergies that improve the accessibility and applicability of technologies. Strengthening partnerships between government institutions, private sector companies, and NGOs can enhance the sharing of agricultural innovations. The private sector's participation is critical for large-scale technology deployment, but its profitability must be addressed through policy reforms. Public-private partnerships (PPPs) can help reduce financial barriers for private companies by offering subsidies, grants, or favourable policies that encourage investment in agricultural technology distribution. A collaborative approach between these sectors can also help mitigate issues such as high seed costs and limited credit access for farmers (Farm Square, 2022) [30].

8. Future Prospects for Agricultural Technology in Nigeria

Emerging technologies are poised to revolutionize Nigerian agriculture by enhancing efficiency, sustainability, and profitability. Various advanced technologies are becoming central to modern farming practices as the agricultural landscape evolves. These innovations offer significant potential for improving the productivity of Nigerian farmers, particularly smallholders and addressing key challenges such as resource management and crop marketability.

a) Precision Agriculture

Precision agriculture, which leverages tools such as GPS and other technological systems, has the potential to transform Nigerian farming practices significantly. Precision farming enables farmers to optimize inputs like water, fertilizers, and pesticides by collecting data on soil conditions, crop health, and environmental factors. This results in higher yields, better soil health, and more sustainable farming practices (Umar, 2022) [83]. For example, monitoring soil fertility through precision agriculture prevents over-fertilization, reducing waste and negative environmental impacts (Falodun, 2019) [29]. This technology offers a path to more efficient and environmentally friendly farming, particularly in Nigeria's diverse agroecological zones.

b) Weather Tracking Technology

Accurate and timely weather forecasting is critical for effective agricultural planning and risk management. Weather tracking technology provides farmers with real-time updates on weather conditions, allowing them to anticipate adverse weather events and take preventive measures to protect crops. This technology helps minimize crop losses due to unpredictable weather, thus increasing farmers' resilience to climate change (Umar, 2022) [83].

c) Satellite Imaging

Satellite imaging offers real-time crop imagery, which is valuable for monitoring crop growth and detecting potential issues without needing on-site visits. This technology not only saves time and money but also enables farmers to track the health of their crops over large areas. Satellite data can be integrated with soil and water resource information to notify farmers when certain environmental thresholds are exceeded, helping them to take timely corrective actions (Umar, 2022) [83].

d) Artificial Intelligence (AI)

Artificial intelligence is transforming the agricultural industry with innovations such as drones, robotic harvesters, and autonomous tractors. These technologies streamline

tasks like planting, harvesting, and soil maintenance, reducing the need for manual labour and enhancing operational efficiency. AI-driven solutions can also improve decision-making processes through data analysis, helping farmers make more informed choices about crop management ((Falodun, 2019; Umar, 2022) [29, 83]. AI's role in agriculture is expected to grow rapidly, offering farmers advanced tools to increase productivity while reducing costs and labour.

e) Radio Frequency Identification (RFID) Technology

RFID technology, which uses radio waves to identify tagged objects, can provide farmers with valuable data about the farm produce, including details about soil conditions and crop yield. For example, a tagged bag of potatoes could provide information on the soil where it was grown, allowing for better traceability and quality control. RFID can potentially improve the supply chain, helping farmers and consumers gain access to more detailed information about the origin and quality of agricultural products (Umar, 2022) [83].

The future of Nigerian agriculture is filled with promising prospects driven by emerging technologies that enhance efficiency, sustainability, and productivity. As these technologies, such as precision agriculture, AI, and weather tracking, become more widely adopted, they will revolutionize farming practices and open up new opportunities for growth in the sector. Nigeria can maximize the potential of these innovations, positioning the country to meet the challenges of food security and agricultural development in the coming years.

9. Conclusion

This study has highlighted the critical factors influencing the adoption of modern agricultural technologies among smallholder farmers in Nigeria. The key drivers identified include economic barriers such as limited access to credit, high technology costs, and inadequate infrastructure. Social and cultural factors, including low education levels and gender dynamics, also significantly shape farmers' willingness to adopt new innovations. Additionally, the findings underscore the importance of tailoring technologies to Nigerian farmers' unique socioeconomic and agroecological conditions and addressing the barriers that hinder the widespread uptake of modern farming practices.

Addressing these key drivers is crucial for unlocking the full potential of agricultural technologies in Nigeria. By improving infrastructure, offering targeted financial support, and enhancing education and training programs, stakeholders can significantly improve farmers' ability to adopt and benefit from modern agricultural innovations. Furthermore, increasing awareness and providing localized solutions that consider cultural norms and regional differences will foster greater acceptance and adoption among farmers.

We call on all stakeholders, government agencies, non-governmental organizations (NGOs), the private sector, and agricultural institutions to collaborate and create an environment enabling them to adopt agrarian technologies effectively. Only through coordinated efforts can Nigeria achieve sustainable agricultural growth, improve food security, and enhance the livelihoods of its farmers, aligning with national and global development goals.

10. Recommendations

The successful adoption of modern agricultural technologies in Nigeria is critical for boosting productivity, ensuring food security, and promoting sustainable farming practices. However, several barriers, including limited infrastructure, inadequate training, and resistance to change, hinder farmers' adoption of these technologies. Policymakers and stakeholders must address these challenges to create an enabling environment for farmers to adopt and benefit from modern agricultural innovations.

1. Policy interventions should create affordable and accessible credit options, such as low-interest loans, grants, and agricultural subsidies, to help farmers invest in technologies. Public-private partnerships could facilitate financing options that lower the barriers for smallholder farmers.
2. Governments should collaborate with private companies, NGOs, and international organizations to expand the availability of affordable technologies for farmers. Initiatives should focus on scaling up successful models, such as mobile applications and ICT tools, which have already proven effective in promoting agricultural innovation in Nigeria.
3. Government policies should prioritize investments in rural infrastructure to improve accessibility, reduce costs, and support technological advancements in agriculture (Mwangi & Kariuki, 2015) [59].
4. Policymakers should focus on expanding mobile network coverage and internet access in remote areas, enabling farmers to access agricultural information and technology easily.
5. Policymakers should invest in literacy programs and farmer education initiatives to increase awareness of new agricultural technologies (Kafando *et al*., 2022) [40]. These programs should focus on improving general literacy and building specific skills related to modern farming techniques and digital tools.

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