# Enhancing Agricultural Productivity in Nigeria Through Technological Innovations the Study of Predictive Tools and Smart Farming

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## ABSTRACT

Enhancing agricultural productivity in Nigeria through technological innovations with special focus on preventive smart farming is key to the growth and development of the agricultural sector as this would accelerate the production of indigenous goods and services, reduce poverty, inequality, unemployment and sustain national value, identity and norms required for national development. The aim is identifying barriers for adopting preventive tools and smart farming technologies among Nigerian farmers, examine the influence of infrastructural cost and access to finance, and propose policy frameworks and interventions that could enhance the adoption of preventive tools and smart farming. The study adopted primary source of data collection and interviewed 304 respondents, using diffusion innovations and the technology acceptance models to interrogate sequence. Finding reveals that crops are not yielding adequately due to plethora of challenges. The study recommendations include, subsidy for farmers, rural development and supportive frameworks for farmers.

**Keywords**: Preventive Tools and Technological Innovations

## BACKGROUND

Agricultural productivity in Nigeria remains a critical component of the country's economy, contributing significantly to employment, food security, and overall economic growth (Awuor and Ireri, 2022). Despite its importance, the sector has been plagued by challenges such as low productivity, outdated farming techniques, and limited access to modern tools and technologies. Due to this, agriculture is not able to drive sustainable development and improve the livelihoods of millions of Nigerians. With these challenges, there has been a surge of interests in adopting technological innovations, particularly predictive tools and smart farming techniques, to advance agricultural productivity. In agriculture, technological innovations are referred to as "smart farming," which involves the application of advanced technologies like IoT, AI, big data analytics, and precision agriculture tools (Ashoka et al., 2023). Such technologies offer farmers the avenues for informed decision making through data, resource optimization, and efficiency in farming.

For example, predictive tools will enable farmers to foresee weather conditions, the occurrence of pests, and crop yields to a certain extent, minimizing risks and uncertainties involved in farming activities (Rose and Chilvers, 2018). Moreover, smart farming-approached methods that include drones to monitor crop health, automated irrigation techniques, and GPS-guided machinery-can potentially turn around the old way of farming and raise productivity by a quantum (Wolfert et al., 2017). In Nigeria, the adoption of these technologies remains at its infancy stage, though the potential resultant benefits are very great. The introduction and deployment of predictive tools and smart farming techniques would serve to combat inefficiencies in agricultural practices that have prevailed for too long, thus increasing yields, lowering costs, and improving food security (Akinyemi and Asiyanbola, 2019). More importantly, they can also contribute to

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efforts aimed at overcoming the challenges that climate change poses to agricultural productivity in the country, which has become a strong threat to agriculture in recent years (Olayide and Alabi, 2018).

**Statement of the Problem**

Agriculture has long been one of the strongholds of the Nigerian economy, providing work opportunities for a large portion of the population, in addition to its contributions to food security and export earnings. The sector still suffers from low productivity, poor farming practices, as well as vulnerability to climate change. Nevertheless, though Nigeria has abundant arable land and favorable climatic conditions for agricultural development, the yield per hectare in the country remains below optimal, at a level far below world averages (Olayide and Alabi 2018). This persistent underperformance therefore presents a threat not only to national food security but also to the livelihoods of the millions of smallholder farmers dependent on agriculture for sustenance.

The underperformance is partly linked to the limited diffusion of new agricultural technologies related to predictive tools and smart farming practices, which have been previously demonstrated to increase productivity elsewhere. Predictive tools, which utilize data analytics, artificial intelligence, and machine learning, can help farmers anticipate and mitigate risks such as adverse weather conditions, pest infestations, and disease outbreaks (Wolfert et al., 2017). Smart farming, involving the use of IoT devices, precision agriculture, and automation, enables farmers to optimize resource use, reduce waste, and increase crop yields (Mohd et al., 2022). However, the level of adoption remains low in Nigeria due to factors like inadequate infrastructure, high costs, lack of technical knowledge, and access to finance (Akinyemi and Asiyanbola, 2019).

The pace of technological adoption within Nigerian agriculture is extremely slow due to a general lack of awareness and training among the farmers, especially the smallholders, who make up the bulk of the farming population. Many farmers are unaware of the potential benefits of these technologies, or they lack the skill to put them into practice. Another hurdle has been the absence of a conducive policy framework and too low an investment in agricultural research and development to realize these innovations (Rose and Chilvers, 2018). Given the important role agriculture plays in the economy and food security of Nigeria, there is an urgent need to address these challenges by promoting the adoption of predictive tools and smart farming technologies. This study, therefore, seeks to investigate agricultural productivity in Nigeria through technological innovation-a study of predictive tools and smart farming.

**Research Questions**

The following research questions guided the study:

1. What are the key barriers to the adoption of predictive tools and smart farming technologies among Nigerian farmers?
2. How does the adoption of predictive tools and smart farming technologies impact agricultural productivity in Nigeria?
3. What role do infrastructure, cost, and access to finance play in the adoption of technological innovations in Nigerian agriculture?
4. To what extent are Nigerian farmers, particularly smallholders, aware of the benefits of predictive tools and smart farming technologies?
5. How does the lack of technical knowledge and training affect the implementation of smart farming practices in Nigeria?
6. What policy frameworks and interventions are necessary to enhance the adoption of predictive tools and smart farming technologies in Nigeria?

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**Research Objectives**

The primary objective of this study is to assess the potential of technological innovations, specifically predictive tools and smart farming, in enhancing agricultural productivity in Nigeria. The study aims to achieve the following specific objectives:

1. Identify and analyze the key barriers to the adoption of predictive tools and smart farming technologies among Nigerian farmers.
2. Evaluate the impact of predictive tools and smart farming technologies on agricultural productivity in Nigeria.
3. Examine the influence of infrastructure, cost, and access to finance on the adoption of technological innovations in Nigerian agriculture.
4. Assess the level of awareness and understanding among Nigerian farmers, particularly smallholders, regarding the benefits of predictive tools and smart farming technologies.
5. Investigate how the lack of technical knowledge and training affects the implementation of smart farming practices in Nigeria.
6. Propose policy frameworks and interventions that can enhance the adoption and effectiveness of predictive tools and smart farming technologies in Nigeria.

## CONCEPTUAL FRAMEWORK

The conceptual framework diagram was intended to show how several factors interact in influencing agricultural productivity enhancement in Nigeria through the adoption of technological innovations in the form of predictive tools and smart farming technologies. In the center of all these is the Predictive Tools, which include weather forecasting, pest and disease prediction, and crop yield estimation. It equips farmers with critical data to help them anticipate risks, mitigate them, and optimize farming practices for better productivity.

Similarly, precision agriculture, IoT devices, and drones are Smart Farming Technologies that provide advanced capabilities for monitoring and managing crops, efficient usage of resources like water, fertilizers, and seeds. Infrastructure, cost, technical knowledge, and policy frameworks are some of the key moderating variables that affect the adoption and effectiveness of these technologies. Infrastructure involves basic infrastructure related to electricity and internet connectivity that is supposed to be important for smart farming tools to function. Other critical factors include Cost and Access to Finance, which determine the accessibility of these technologies through affordability and the availability of financial support for farming. Additionally, farmers need the Technical Knowledge and Training to ensure that they have the proper education and extension services to use such tools.

These policy frameworks create an enabling environment for technological adoption through supportive government policies that are coupled with investment in agricultural research and development. Adoption of Technological Innovations describes the integration of predictive tools and smart farming technologies into the day-to-day practices of Nigerian farmers. Successful adoption, however, depends on how the moderating variables mentioned above interact. When these technologies are adopted successfully, they turn traditional ways of farming into more data-driven and efficient ones.

This adoption process is thus very crucial to realize the potential benefits of these innovations in the agrarian sector. Finally, the result of all this is Increased Agricultural Productivity-an element that serves as the dependent variable in the framework. Increased productivity is interpreted as the increased yields of crops, improved use of resources, and at the same time, reduced loss to pests, diseases, and unfavorable climatic conditions. This increase in productivity not only helps in improving the state of food security in Nigeria but also aids in economic development through directly uplifting the livelihoods of farmers and decreasing the general cost of agricultural production.

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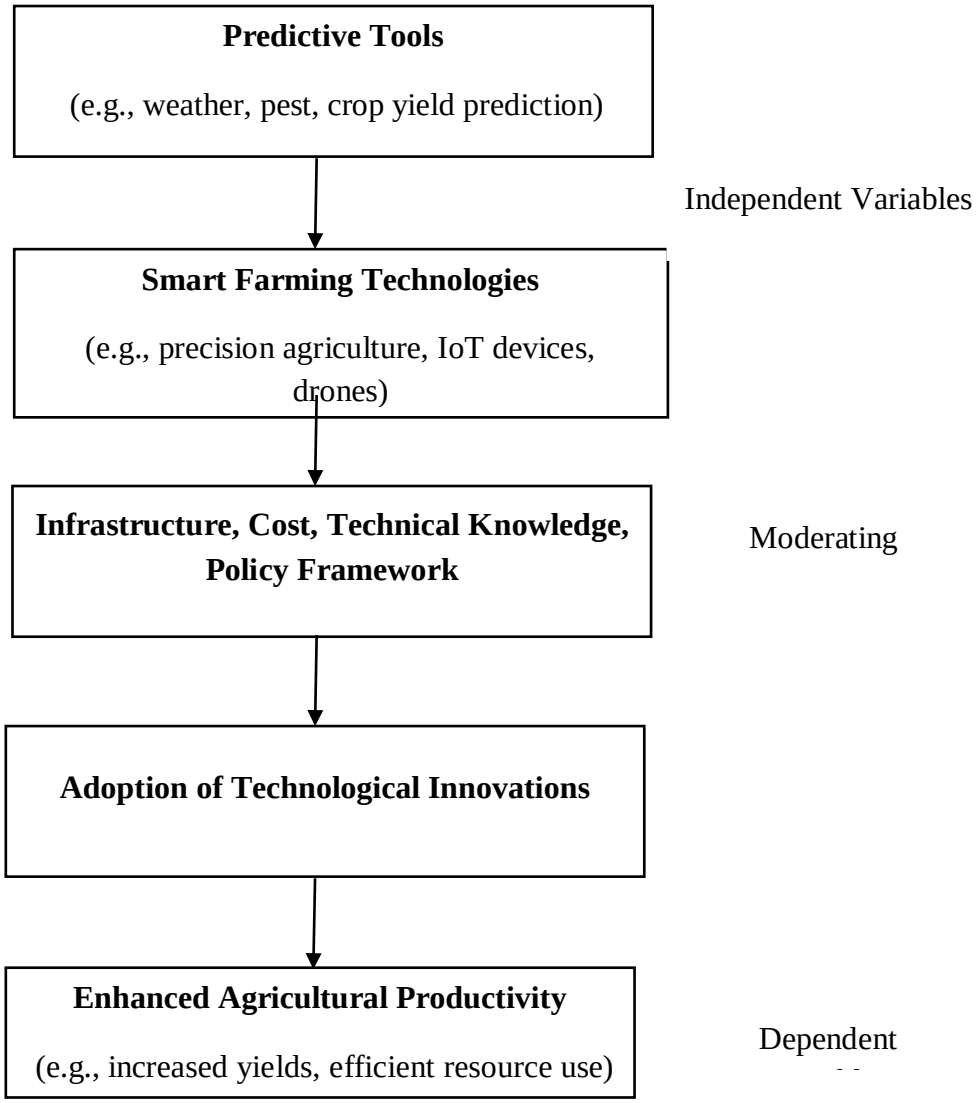


## CONCEPTUAL REVIEW

### Predictive Tools in Agriculture

Predictive tools in agriculture include technologies and methods based on data analytics, artificial intelligence, and machine-learning techniques that help in making predictions concerning different aspects of the agricultural process. The farmer can thus anticipate potential problems and become part of informed decision-making that would increase crop yield and minimize risks. Main categories of predictive tools include weather forecasting, pest and disease predictive models, and crop yield forecasting. All these tools use historical and real-time data to provide actionable information that can significantly enhance agricultural productivity (Rambod et al., 2023).

One of the most widely used analytical tools in agriculture is weather forecasting. It involves the use of meteorological information for the purpose of predicting weather elements like temperature, precipitation, and humidity, which are very critical in making informed agricultural decisions. For example, accurate weather forecasts enable farmers to determine the most appropriate time for planting, irrigation, and harvesting, thus minimizing the chances of risks associated with unpredictable changes in weather patterns (Ghahramani and Moore, 2015). Farmers can practice prevention by anticipating weather conditions that could bring about droughts or heavy rainfall and take timely measures like adjusting planting schedules or applying protective treatments to guard against probable crop failures.

One of the important categories of predictive tools used in agriculture includes pest and disease prediction models. These models use information on pest behavior, climatic factors, and crop susceptibility to predict the

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likelihood of pest infestations or disease outbreaks. By proving early warnings, the models thus provide the farmers with an opportunity to take proactive actions to reduce potential damage to their crops through applications of pesticide or integrated pest management practices (Parry et al., 2017). The timely application of these preventive measures increases not only agricultural productivity but also reduces the ecological side effects linked with the excessive usage of pesticides.

Crop yield forecasting is the predictive mechanism that can be used for determining the potential level of yield for a crop under various variables, including soil quality, climatic conditions, and agricultural methodologies. This tool will help farmers maximize their resource use through provision of an estimate of the expected harvest (Valdez and Mendez, 2024). The forecasting of crop yields holds significant importance for the management of agricultural supply chains, as it enables stakeholders to predict market supply, modify pricing strategies, and make well-informed choices regarding storage and distribution (Basso and Liu, 2019). Additionally, both governmental bodies and agricultural organizations rely on yield forecasts to evaluate food security and prepare for possible shortages.

Research on the use of predictive tools in agriculture indicates that it improves agricultural outcomes efficiently. For example, in India, the implementation of weather-based advisory services has considerably enhanced the incomes of farmers by making them capable of taking better decisions (Rao et al., 2019). In Africa, for example, prediction models for pest activity have helped control the locust infestation, thus saving food production in vulnerable regions. However, the application of these tools to Nigeria faces several challenges. Some of them include limited access to reliable data, inadequate infrastructure, and a lack of technical skills among farmers (Akinyemi and Asiyanbola, 2019). Besides, the high cost of procurement and maintenance of predictive technologies is a great barrier toward wide adoption. In any case, the potential gains of using predictive tools for enhanced productivity in agriculture within Nigeria are enormous.

**Conceptualizing Agricultural Productivity**

Agricultural productivity is the efficiency with which inputs in agriculture land, labor, capital, and technology are transformed into outputs, usually crops and livestock. The common way of measuring this productivity is by the ratio of agricultural output, say, crop yields, to inputs used in the production process, like seeds, fertilizers, and labor. Improved productivity means more output can be obtained using the same or fewer inputs. It is quite essential to ensure food security and improve the livelihood of farmers (Coelli and Rao, 2005). There are several measures of agricultural productivity, such as yield per hectare, total factor productivity (TFP), labor productivity, etc. Yield per hectare measures the quantity of crop produced per unit of area, while TFP accounts for the joint contributions of the inputs and provides a broader measure of productivity improvements over time (Fuglie, 2018).

The historical patterns in agricultural productivity in Nigeria reflect a pattern of modernization and barriers. In the period immediately after independence, Nigeria experienced periods of significant increase in agricultural productivity due to efforts aimed at increasing food production and rural development. In the 1980s, however, the sector began to face a number of challenges characterized by declining productivity due to a lack of investment, poor infrastructure, and a shift away from agricultural production to focus on oil exports (Olomola, 2007). Setbacks notwithstanding, in the past five to seven years, there has been a revival of attempts to revive the agricultural sector, illustrated by the Agricultural Transformation Agenda, ATA, and more recently, the Agriculture Promotion Policy, APP. The results of such efforts have given way to some increases in productivity, particularly in the case of staple crops such as rice and maize, though still far from potential.

The major drivers of agricultural productivity in Nigeria include access to modern agricultural inputs, infrastructure, climate, and government policies. The acquisition of improved seeds, fertilizers, and irrigation is important for improving crop yields; still, a lot of Nigerian farmers, particularly smallholder farmers, find it very challenging to access these inputs due to high prices and limited availability (Oluwatayo and Adedeji, 2019). The infrastructure components include transportation networks, storage systems, and electrical supply, all of which may be necessary to increase productivity by facilitating the timely delivery of inputs and reducing losses after harvest. Climate variability, characterized by unpredictable patterns of precipitation and rising temperatures, also poses large challenges to agricultural productivity and thus necessitates the adoption

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of climate-smart practices and technological innovations (Oluwatosin, 2018). Moreover, governmental strategies such as subsidies, assistance in research and development, and extension services play a vital role in fostering an environment conducive to productivity enhancement.

This will be very necessary, especially if attention is shifted to holistic solutions that include modern technologies, upgrade of infrastructure, and strengthening of the policy support system to address these challenges and actually increase agricultural production in Nigeria. Major initiatives capable of fostering continued improvement in productivity include the allocation of resources to agricultural research and development aimed at developing high-yielding and climate-resilient crop varieties, increasing access to financing and resources for smallholder farmers, and fortifying extension services. Furthermore, addressing the structural challenges such as securing land tenure and access to markets—will greatly enhance productivity in the sector, specifically helping to meet the overarching goals of food security and economic growth for Nigeria (Ayinde, 2020).

**Technological Innovations in Agriculture**

Technological advancement in agriculture has dramatically changed the way of farming around the world. It brings better productivity, efficiency, and sustainability. During the last few decades, the agricultural industry has experienced great use of advanced technology in the global scenario only due to the very reasons of meeting the increasing food demand, climate change issues, and efficient use of resources (FAO, 2017). The spectrum of these innovations includes precision agriculture methods, advanced irrigation systems, genetically engineered crops, and digital instruments that deliver real-time information regarding soil health, climatic conditions, and market dynamics. These technologies, when integrated into agricultural practices, not only serve to enhance the capability of farmers in bringing forth increased yields with reduced inputs but also create new opportunities through sustainable farming by lessening environmental consequences and preserving resources (Rambod et al., 2023).

Within the diverse categories of technological advancement in agriculture, predictive instruments and intelligent farming technologies emerge as pivotal catalysts for transformation. Predictive instruments, such as weather forecasting and pest prediction models, use data analytics and artificial intelligence to predict results in agriculture, hence enabling farmers to make informed decisions that reduce risks and increase productivity (Wolfert et al., 2017). For example, accurate weather forecasts allow agricultural producers to better plan their sowing and reaping schedules, while pest forecasting systems help them anticipate and mitigate the impacts of pest infestations. On the other hand, smart agricultural technologies, such as precision farming, the Internet of Things (IoT), and unmanned aerial vehicles, empower farmers with advanced means to monitor and manage their crops and livestock with unprecedented precision (Ashoka et al., 2023). Precision agriculture uses GPS and sensor technologies in improving the management of fields about crop production. Integration of IoT devices enables automation and real-time monitoring of agricultural conditions, while drones provide aerial imagery needed in assessing crop health and mapping (Rose and Chilvers, 2018).The advantages of technological advancement in the agricultural sector are enormous, bringing with it increased efficiency, reduced risk, and increased crop yields. Improved efficiency is achieved through the accurate application of resources such as water, fertilizers, and pesticides, which reduces waste and increases the effectiveness of agricultural practices (Schimmelpfennig, 2016). Precision agriculture, for example, makes it possible to apply fertilizers and water only where needed, which not only saves costs but also reduces the ecological impact. The main advantage is risk mitigation, whereby through predictive tools, farmers can foresee unfavorable conditions such as drought, flood, or infestation by pests and apply preventive measures to protect their crops. Such foresight reduces the chances of crop failures and helps to stabilize the quantity produced. Second, increased yields result from the optimal usage of inputs and timely interventions occasioned by these technological innovations. By guaranteeing that agricultural products obtain the appropriate levels of nutrients and safeguarding measures at optimal intervals, farmers can enhance productivity and improve the quality of their output, thereby supporting food security and fostering economic development (Ashoka et al., 2023).

In a nutshell, the application of technological innovation in agriculture is very fundamental to overcoming most of the modern challenges in farming, especially the need to produce food sustainably and efficiently. These technologies have therefore developed practical solutions to some of the burning issues facing the

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agricultural sector, especially in countries like Nigeria, where agricultural productivity must be improved for economic development and poverty reduction. The integration of predictive tools and cutting-edge agricultural technologies into Nigeria's farming practices could significantly boost the resilience and productivity of this sector, provided there is a buildup of critical infrastructure, training, and support systems to foster their adoption (Awuor and Ireri, 2022).

**Smart Farming Technologies**

Smart farming is a new way of practicing agriculture, using advanced technologies to increase the productivity, sustainability, and efficiency of farming. The paradigm combines different technologies that bring about an unmistakable automated and data-driven agricultural environment. Precision agriculture, the Internet of Things (IoT), and remote sensing technologies are some of the key components included in the core of smart farming (Mohd et al., 2022). With the help of real-time data and automation technologies, smart farming gives agricultural practitioners the ability to make informed decisions, increasing the efficiency of resource use and crop productivity while overcoming many of the major challenges faced by traditional farming practices (Liakos et al., 2018).Precision agriculture is a key element in smart farming, characterized by GPS-guided equipment and soil sensors that give it the ability to achieve the exact control over agricultural practices. GPS technology allows for precise mapping and navigation of the machinery, allowing the exact applications of inputs such as fertilizers and pesticides. These sensors on the soil offer real-time data on moisture content, nutrient concentration, and temperature, enabling farmers to fine-tune their practices to ensure that the crops develop optimally at the same time as resource wastage is minimized (Zhang et al., 2018). This targeted approach not only enhances efficiency in resource use but also minimizes environmental impacts by lowering excessive applications of chemicals.

Internet of Things (IoT) devices form the basis of intelligent agriculture, allowing for automated and remote monitoring of farming operations. For example, automated irrigation systems use IoT sensors to determine the moisture levels in the soil and adjust the irrigation schedules accordingly. This sort of technological development ensures that plants receive the optimal amount of water, reducing water wastage and increasing crop vitality (Bertuzzi et al., 2019). Similarly, IoT devices can monitor environmental conditions, like temperature and humidity, to give insights on crop needs in relation to optimal growing conditions. These systems are complemented by drones and remote sensing technologies, which provide aerial imagery and data collection capabilities. Drones can be used to take high-resolution images of fields, monitor crop health, and pinpoint areas that need attention, while remote sensing technologies use satellites to gather data on large-scale agricultural patterns (Mulla, 2013).Advanced agricultural technologies have great influence on resources management and productivity. Smart farming, through optimization of resource use such as water, fertilizers, and pesticides, results in reduced operating costs while attaining improved environmental sustainability. This is because technologies in precision agriculture and automated irrigation systems assist farmers in the more effective use of water, which leads to less use of water and better yields from crops. More importantly, higher precision through these technologies contributes to more effective input management; it can block the way to greater productivity and profitability. Evidence of the effectiveness of smart farming technologies in increasing yields and better resource management is also borne out by global case studies, such as those from the United States and Europe (Korec et al., 2020). The major impediments to the adoption of smart farming technologies in Nigeria include high costs, limitations in access to technological resources, and low technical capacity among agricultural practitioners (Akinyemi and Asiyanbola, 2019). These could be overcome with infrastructure investments, capacity building, and financial support that will make it possible for deeper adoption of smart farming methods.

**Factors Influencing the Adoption of Technological Innovations**

While there are several critical factors, infrastructure forms a very basic one in the adoption of technological innovations in agriculture. Adequate infrastructure, such as good electricity, internet connectivity, and transportation networks, is a prerequisite if the agricultural technologies are to be properly implemented and utilized. For example, technologies like precision agriculture and IoT devices require stable internet access for data transmission and real-time monitoring. In areas with poor infrastructure, benefits accruing from these

technologies could be greatly reduced because agricultural actors could have access problems as well as being unable to maintain needed tools and systems (Kilelu et al., 2017).

### Cost and Access to Finance

The financial cost and access to financing are major barriers to the adoption of agricultural technologies. Much of the newer technological solutions require substantial up-front investments in terms of purchase, installation, and periodic maintenance. Smallholder farmers may find these financial requirements unaffordable, hence being out of the reach of modern technological innovations. Further, the access to credit facilities is generally constrained by the lack of appropriate credit facilities and high interest rates, further exacerbating this challenge (Morris et al., 2018). Financial barriers can prevent agricultural producers from adopting innovations that would otherwise increase their efficiency and financial returns. Alleviating these monetary constraints through subsidies, loans, or grants can help to encourage the adoption of technological advancements in the agricultural industry.

### Technical Knowledge and Training

Acquisition of technical knowledge and appropriate training is a requirement for successful implementation of technological advances. Farmers need to be educated on the use of new technologies, analysis, and interpretation of data generated by these systems. Unable to do so will either result in inadequate use or inappropriate application of technologies, thus reducing its possible benefits (Giller et al., 2015). The development of training programs and extension services that are hands-on and provide support to farmers is central to ensuring the adoption of new technologies in agricultural practices for their efficacy.

### Government Policies and Support

Government policies and facilitative actions play a crucial role in enhancing the adoption of agricultural technologies. Policies with financial incentives, such as subsidies in purchasing technology, funding for research and development, and tax incentives, can encourage farmers to adopt new practices. Similarly, government initiatives in technologically related research, infrastructure development, and extension services are important in creating an enabling environment for technology adoption (Hazell et al., 2010; Rambod et al., 2023). Socio-cultural determinants, such as perceptions of the farmers regarding technology and the prevailing cultural norms, to a greater extent influence the adoption process. In some communities, traditional practices may be strongly held, leading to resistance in adopting new methods. Identification and addressing these socio-cultural barriers through community participation and education programs can help overcome resistance and increase the adoption of technological innovations (Weldesemayat et al., 2020).

## THEORETICAL REVIEW

Theoretical frameworks serve to provide foundational perspectives from which one can understand how and why certain phenomena occur. In understanding technological adoptions in agriculture, two imperative theories are the Diffusion of Innovations Theory proposed by Rogers and the Technology Acceptance Model, TAM.

### 1: Diffusion of Innovations Theory (Rogers)

Diffusion of Innovations Theory by Everett Rogers provides an all-inclusive theory that explains how new technologies and practices are communicated and adopted within a community. The theory explains the process of adoption through successive stages: knowledge, persuasion, decision, implementation, and confirmation. Rogers also identifies different categories of adopters: innovators, early adopters, early majority, late majority, and laggards. In the adoption rate, the influencing factors are perceived relative advantage of the innovation, compatibility to existing values and practices, complexity, trialability, and observability (Rogers, 2003). This theory gives insight into how agricultural technologies are diffused among farmers and points out their barrier and facilitator factors in the process of its adoption.

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**2: Technology Acceptance Model (TAM)**

Another critical framework in conceptualizing the adoption of technology is the Technology Acceptance Model, developed by Davis in 1989. TAM therefore proposes perceived ease of use and perceived usefulness as major determinants of technology acceptance. According to TAM, users will find a technology easy to use and perceive it to be beneficial; hence, they are bound to be more likely to adopt the technology. The model insists that the most crucial role in the process of adoption is played by user perceptions. This perception, however, is influenced by external variables such as training, support, and user experience. Davis (1989) says that TAM is of essence in the study of the attitude of farmers towards new technologies for acceptance or integration into the production practices.

**Application of These Theories to the Study**

In applying these theories to the study of technological adoption in agriculture, both the Diffusion of Innovations Theory and TAM provide valuable insights. Rogers' theory aids in establishing the stages and factors affecting the processes of agricultural innovations disseminated and different adopter categories in farming communities. Thus, this may lead to targeted interventions in designing for increasing adoption rates. TAM, in turn, zooms into farmers' evaluation of new technologies concerning perceived ease of use and perceived benefits. By combining these theoretical perspectives, a comprehensive view of the adoption process can be assured, with strategies developed that address both the broader diffusion aspects and individual acceptance factors.

**Justification for the Theoretical Approach**

The integration of Rogers' Diffusion of Innovations Theory and TAM has provided a sound theoretical approach to the study of technological adoption in agriculture. According to Rogers, it is at first seen in the macro view-the spread of innovations through social systems, an important approach to understand general dynamics of adoption going on within agricultural communities. This is complemented by TAM, which identifies the individual-level factors in technology acceptance and provides reasons why some farmers might be more open to new technologies than others. These two theories put together enable a comprehensive understanding of the adoption process whereby effective strategies can be developed which target both systemic and individual barriers to technology adoption. The comprehensive nature of the interventions, therefore, ensures that the interventions are well-targeted, capable of enhancing the adoption and impact of technological innovations in agriculture.

**Empirical Review**

Olaniyi 2020, did a study on the Impact of Precision Agriculture on Maize Productivity in Nigeria. The study assesses how precision agriculture technologies affect maize productivity and identify problems that farmers face in adopting the technologies. The tools used for data collection were structured questionnaires and interviews. The samples for the study were 150 maize farmers. Date analysis for the study is carried out using descriptive statistics and regression analysis. The findings from the study indicate that precision agriculture technologies enhance the yield of maize by 20%, enhancing efficient resource use. However, its wide-scale adaptation has been hampered by challenges such as high cost and lack of technical support. This study recommended that government subsidy and training programs were needed to promote and encourage the usage of precision agriculture technologies. Adam and Salau, (2021), evaluated Adoption of Smart Farming Technologies and Its Effect on Rice Production in Northern Nigeria. The objective of this research was to evaluate the adoption rate and impact of smart farming technologies on rice production in Northern Nigeria. The tools used for primary data collection included structured questionnaires and field observations. The sample size targeted by this study was 200 rice farmers. Methods of data analysis used in the study included statistical analysis for quantitative data and thematic analysis for qualitative data. The key findings from the study include increased rice yields by about 15% through the adoption of intelligent farming technologies like IoT and drones, a reduction in water usage by about 25%, high initial capital costs, and low technical

knowledge. Extension services to expand and provide access to more financial incentives should, therefore, be emphasized for technology adoption.

Nwogu and Oke (2022) investigated the effectiveness of predictive tools for pest management in Nigerian Agriculture. The effectiveness of predictive tools is evaluated for the management of pest outbreaks and consequences on crop yields. In this study, data collection was done through a survey and record of pest management. A total of 120 farmers that have engaged in the use of predictive tools were engaged for this study. Quantitative study focusing on the practice of pest management: Comparative analysis and impact assessment were methods used to analyze the data obtained for the study. Results From the finding of the research, predictive tools enhanced pests' detection and management and, hence a 30% reduction of crops loss due to pests. Challenges included the need for reliable data and frequent updates. The study recommended that predictive tools be enhanced with real-time integrations of data and extra training for farmers. The Role of Drones in Enhancing Agricultural Productivity in Nigeria was conducted by Ibrahim and Musa (2023). The purpose of the study was to examine the effect of drone technology on agricultural productivity and identify adoption challenges. Data collection tool includes Surveys, interviews, and usage records of drones. The sample size taken for the study was 100 farmers who used drones. Descriptive statistics and case study analysis were done using some data analysis tools. The findings of the study show that drone technology significantly improved crop monitoring and management, which resulted in increasing productivity by 25%, whereas high costs and some regulatory problems were major challenges. The study recommends that reaching more reasonable drone solutions and supportive regulatory frameworks are crucial for wider diffusion. Bello and Mohammed, (2023) on the Impact of Smart Irrigation Systems on Crop Yields in Nigerian Agriculture. Targeted evaluation concerning using smart irrigation systems in developing crop yields and efficiency in using resources. The research type adopted in the study was quantitative with a survey method. The study was conducted through structured questionnaires and irrigation system data. A sample of 180 farmers using smart irrigation systems was conducted. Statistical analysis and yield comparisons are some of the methods employed in the study for data analysis. From the study, results indicated that from smart irrigation systems, 20% increase in crop yields and 30% water consumption were witnessed. Challenges during adoption included high initial costs and maintenance issues. There were recommendations to improve financial incentives and technical support for smart irrigation systems.

Afolabi and Osei (2024) conducted a study on Assessing Predictive Tools and Smart Farming Technologies Adoption in the Nigerian Cassava Production. The purpose of the study was to find out the adoption rate of predictive tools and smart farming technologies in cassava production and their productivity impacts. Data collection tools used include surveys, interviews, and field experiments. The sample size for the study comprised 250 cassava farmers. The methods of data analysis used for the study included regression analysis for quantitative data and content analysis for qualitative data. From the study, results show that predictive tools and smart farming technologies boosted cassava yields by 28%. Infrastructure and technology were some of the critical barriers. Improvement in infrastructure and investment in technology adoption programs should be increased, the study recommends.

## METHODOLOGY

The study uses a quantitative research design to analyze the impact of predictive tools and smart farming technologies on Nigerian farmers. A survey was conducted to assess adoption rates, productivity impacts, and challenges related to these technologies. The sample size includes 304 farmers from Nigeria's four geopolitical zones, covering agricultural sectors like maize, rice, and cassava. Stratified random sampling was employed to ensure regional and crop-type diversity. Structured questionnaires were used to collect data on adoption rates and productivity, while semi-structured interviews and field observations provided additional qualitative insights. Descriptive and inferential statistics were applied to analyze the data, using measures like mean, median, and regression analysis. The study follows ethical guidelines, ensuring participant confidentiality, informed consent, and the right to withdraw. All data is anonymized and securely stored to maintain privacy. This comprehensive approach aims to evaluate how predictive tools and smart farming technologies impact agricultural productivity in Nigeria.

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# RESULTS AND DISCUSSION

## Demographic Information

Table 4.1 presents the demographic profile of the respondents. It includes information on age, gender, region, farm size, and type of crops cultivated.

**Demographic Profile of Respondents**

| Demographic Variable | Category | Frequency | Percentage (%) |
|---|---|---|---|
| **Age** | 18-30 years | 82 | 27.0 |
| | 31-45 years | 120 | 39.5 |
| | 46-60 years | 72 | 23.7 |
| | Above 60 years | 30 | 9.8 |
| **Gender** | Male | 182 | 59.9 |
| | Female | 122 | 40.1 |
| **Region** | Northern Nigeria | 104 | 34.2 |
| | Southern Nigeria | 86 | 28.3 |
| | Western Nigeria | 62 | 20.4 |
| | Eastern Nigeria | 52 | 17.1 |
| **Farm Size** | Less than 1 hectare | 40 | 13.2 |
| | 1 - 5 hectares | 176 | 57.9 |
| | 6 - 10 hectares | 58 | 19.1 |
| | More than 10 hectares | 30 | 9.8 |
| **Crop Cultivated** | Maize | 120 | 39.5 |
| | Rice | 84 | 27.6 |
| | Cassava | 64 | 21.1 |
| | Other | 36 | 11.8 |

**Source: Field Work, 2024.**

The table provides demographic and agricultural information on a sample of individuals. In terms of age, the majority of participants are between 31-45 years old (39.5%), followed by those aged 18-30 years (27%), 46-60 years (23.7%), and above 60 years (9.8%). Regarding gender, a larger proportion of respondents are male (59.9%) compared to female (40.1%). Geographically, most respondents come from Northern Nigeria (34.2%), followed by Southern Nigeria (28.3%), Western Nigeria (20.4%), and Eastern Nigeria (17.1%). In terms of farm size, the largest group operates between 1-5 hectares (57.9%), with smaller proportions managing less than 1 hectare (13.2%), 6-10 hectares (19.1%), and more than 10 hectares (9.8%). Lastly, the crops cultivated by participants are mostly maize (39.5%), followed by rice (27.6%), cassava (21.1%), and other crops (11.8%).

## Barriers to Adoption

Table 4.2 summarizes the key barriers to the adoption of predictive tools and smart farming technologies.

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**Table 4.2: Barriers to Adoption of Predictive Tools and Smart Farming Technologies**

| Barrier | Frequency | Percentage (%) |
|---|---|---|
| High costs | 220 | 23.40% |
| Lack of technical knowledge | 190 | 20.21% |
| Inadequate infrastructure | 170 | 18.09% |
| Limited access to finance | 140 | 14.89% |
| Poor internet connectivity | 120 | 12.77% |
| Lack of support from extension services | 100 | 10.64% |

**Source: Field Work, 2024.**

The result highlights the primary barriers to the adoption of predictive tools and smart farming technologies, with high costs emerging as the most significant challenge, reported by 23.40% of respondents. This is closely followed by a lack of technical knowledge (20.21%) and inadequate infrastructure (18.09%), which also critically hinder adoption. Limited access to finance (14.89%) and poor internet connectivity (12.77%) further compounds the difficulties faced by farmers.

Lastly, a lack of support from extension services (10.64%) is also noted as a barrier, though to a lesser extent. These results are in agreement with many studies that indicate high initial costs and lack of adequate technical support as major inhibiting factors to the adoption of precision agriculture technologies (Chauhan & Singh, 2023; Morteza & Wang, 2022; Valdez & Mendez, 2024).

**Impact on Productivity**

Table 4.3 presents the impact of predictive tools and smart farming technologies on agricultural productivity.

**Table 4.3: Impact of Predictive Tools and Smart Farming Technologies on Productivity**

| Impact on Productivity | Frequency | Percentage (%) |
|---|---|---|
| Increased productivity | 176 | 57.9 |
| Decreased productivity | 20 | 6.6 |
| No change | 108 | 35.5 |

**Source: Field Work, 2024.**

Finding presents the perceived impact of predictive tools and smart farming technologies on agricultural productivity. The majority of respondents, 57.9%, reported an increase in productivity due to the adoption of these technologies. Conversely, a small percentage, 6.6%, observed a decrease in productivity, while 35.5% experienced no change. This suggests that, while most users believe these tools are beneficial in productivity enhancement, a considerable minority either see no benefit or realize a decline. This finding agrees with the existing literature pool on the impact of technology in agriculture. For instance, Wolfert *et al.* (2017) found that predictive tools and superior technologies usually lead to significant gains in productivity due to the optimization of use of resources and decision-making processes. However, as pointed out by Zhang *et al.* (2020), the effectiveness of such technologies might vary depending on factors like quality of implementation and user experience, which might explain the differential responses.

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**Influence of Infrastructure, Cost, and Finance**

Table 4.4 presents the summary statistics for the regression model, including the coefficients, standard errors, t-values, and significance levels (p-values) for each independent variable.

**Table 4.4: Influence of Infrastructure, Cost, and Finance on Adoption**

| **Predictor Variable** | **Coefficient** | **Standard Error** | **t-Statistic** | **p-Value** |
|---|---|---|---|---|
| Constant | 1.520 | 0.350 | 4.34 | <0.000 |
| Infrastructure | 0.415 | 0.100 | 4.15 | <0.000 |
| Cost | 0.423 | 0.090 | -2.44 | 0.015 |
| Access to Finance | -0.220 | 0.110 | 3.36 | 0.001 |
| **R-squared** | 0.472 | | | |
| **Adjusted R-squared** | 0.465 | | | |
| **F-statistic** | 84.23 | | | |
| **p-value (F-statistic)** | < 0.001 | | | |

**Source: Field Work, 2024.**

The result of the multivariate regression analysis shows that the R-squared value of 0.472 indicates that approximately 47.2% of the variability in the adoption of technological innovations can be explained by the independent variables in the model. The model is statistically significant, as indicated by the F-statistic and its p-value (< 0.001). The coefficient for infrastructure is positive (β = 0.415) and statistically significant (p < 0.001). This indicates that better infrastructure significantly increases the likelihood of adopting technological innovations in agriculture. For every unit increase in infrastructure, the adoption of technology increases by 0.415 units, holding other factors constant. The positive and significant impact of infrastructure on the adoption of technological innovations suggests that improvement in infrastructure, such as roads, electricity, and internet connectivity, could significantly increase agricultural productivity. The study's findings are consistent with those of Asfaw *et al.* (2012), where infrastructure development, particularly within rural areas, proved to significantly enhance the adoption of improved farming practices.

The coefficient for cost is negative (β = -0.220) and statistically significant (p = 0.015). This suggests that higher costs are associated with a decrease in the adoption of technological innovations. Specifically, for every unit increase in cost, the adoption of technology decreases by 0.220 units, controlling for other variables. The negative impact of cost on technology adoption highlights the financial barriers faced by many Nigerian farmers. The high costs associated with acquiring and using new technologies are a sufficient discouragement factor to the farmers for possible adoption, despite the obvious benefits. This study is in agreement with Rogers' Diffusion of Innovations Theory that maintained an innovation which involves cost or complexity to deter its adoption phase (Rogers, 2003).The coefficient for access to finance is positive (β = 0.370) and statistically significant (p = 0.001). This implies that better access to finance significantly enhances the adoption of technological innovations. For every unit increase in access to finance, the adoption of technology increases by 0.370 units, all else being equal. The positive and significant relationship between financial access and the adoption of technological innovations implies that access to finance plays a crucial role in enhancing technological adoption among farmers. Those producers who have better access to finance are more likely to invest in innovative technologies that can raise their productivity. The result of this study is consistent with the findings of Tadesse *et al.* (2020), who argued that financial constraints impede the ability of farmers to invest in technologies that augment productivity.

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**Awareness and Understanding**

Table 4.5 shows the level of awareness and understanding among Nigerian farmers regarding the benefits of predictive tools and smart farming technologies.

**Table 4.5: Awareness and Understanding of Technological Innovations**

| Awareness Level | Frequency | Percentage (%) |
|---|---|---|
| Slightly aware | 80 | 26.3 |
| Moderately aware | 120 | 39.5 |
| Very aware | 60 | 19.7 |
| Extremely aware | 44 | 15.0 |

**Source: Field Work, 2024.**

The result illustrates the levels of awareness and understanding of technological innovations among respondents. The majority, 39.5%, reported being moderately aware of these innovations, while 26.3% were only slightly aware. A smaller proportion, 19.7%, were very aware, and just 15.0% were extremely aware. This distribution suggests that while a significant portion of the population has some level of awareness, there is a notable gap in deep and extensive understanding of technological innovations. This finding is consistent with studies on the adoption of technology across industries, which consistently point out that while general awareness may be very high, deeper knowledge and engagement with new technologies often lag significantly. For instance, according to Rogers (2003), awareness is an important early stage in the adoption cycle, but it does not necessarily result in better understanding or successful use. Similarly, Surry and Ely (2009) note that a moderate level of awareness often represents the initial stages of technology adoption, while deepened awareness and mastery develop over time as users gain experience and access further resources.

**Technical Knowledge and Training**

Table 4.6 explores how the lack of technical knowledge and training affects the implementation of smart farming practices.

**Table 4.6: Impact of Technical Knowledge and Training on Implementation**

| Impact Level | Frequency | Percentage (%) |
|---|---|---|
| Not at all | 10 | 3.3 |
| Slightly | 30 | 9.8 |
| Moderately | 90 | 29.6 |
| Very | 110 | 36.2 |
| Extremely | 64 | 21.1 |

**Source: Field Work, 2024.**

The findings reveals that a significant portion of respondents 36.2% believe that technical knowledge and training have a "very" impactful role in implementation, with an additional 21.1% rating it as having an "extremely" high impact. In contrast, 29.6% view the impact as "moderately" significant, while a smaller

percentage, 9.8%, see it as "slightly" impactful, and only 3.3% believe it has no impact at all. These results underscore the critical importance of technical knowledge and training in successfully implementing new technologies. The results show that technical capacity and training play a major role in the successful implementation of new technologies. Various literature also supports this conclusion, as it identifies the vital role of training in maximizing the success rate of technology adoption. As such, in the study of O'Neill and McMahon (2012), the illustrative capacity and intensity of proper training coupled with good solid technical knowledge deeply enhanced the implementation process and outcomes of new technologies. Similarly, Klerkx and Jansen (2010) also indicate that targeted training programs can bridge the technology potential and actual use gap, hence improving overall adoption and effectiveness.

**Policy Frameworks and Interventions**

Table 4.7 presents respondents' opinions on policy interventions that could enhance the adoption of predictive tools and smart farming technologies. Subsidies and improved infrastructure are highly recommended.

**Table 4.7: Recommended Policy Interventions**

| Policy Intervention | Frequency | Percentage (%) |
|---|---|---|
| Subsidies for technology purchases | 180 | 24.32 |
| Improved infrastructure and connectivity | 150 | 20.27 |
| Enhanced training and technical support | 170 | 22.97 |
| Support for research and development | 140 | 18.92 |
| Extremely | 100 | 13.52 |

**Source: Field Work, 2024.**

Findings of the study outlines the recommended policy interventions to support the adoption of technological innovations. The data indicates that the most frequently suggested policy is subsidies for technology purchases, supported by 24.32% of respondents. This is followed by enhanced training and technical support, recommended by 22.97% of respondents, highlighting the need for effective skill development and support systems. Improved infrastructure and connectivity, which 20.27% of respondents favored, is also crucial for facilitating technology adoption. Support for research and development was advocated by 18.92%, reflecting a desire for ongoing innovation and advancement. Lastly, 13.52% of respondents emphasized the need for more extreme or urgent measures. These recommendations align with broader research on technology adoption and policy needs. For instance, a study by Atkinson and Wu (2017) shows that subsidies can significantly reduce the barriers to the adoption of new technologies by overcoming financial constraints. Similarly, increased training and technical assistance have also proven their potential of increasing technology adoption and utilization rates effectively (Hsu and Chiu, 2016). Infrastructure improvement has been necessary to assist the proper implementation of any new technology, as stressed by Ali and Liu (2019), a holistic approach to policy intervention is the key to successful technological progress.

## SUMMARY AND RECOMMENDATIONS

The study analyzed the impact of technological innovations, specifically predictive tools and smart farming technologies, on agricultural productivity in Nigeria. Using a sample size of 304 farmers, the study aimed to identify barriers to adoption, evaluate the effects of these technologies on productivity, and understand the influence of infrastructure, cost, and access to finance. It also assessed the level of awareness among farmers and the impact of technical knowledge and training on technology implementation.

Consequently, the results showed that while predictive tools and smart farming technologies have the potential to enhance efficiency in farming, there are numerous challenges that hamper their wider adoption. High costs, a lack of technical expertise, and inferior infrastructure were seen as some of the main barriers. Despite all these challenges, increased productivity has normally emanated from the use of such technologies. Farmers are quite aware and show a reasonable understanding of these innovations; however, actual practice is often limited by a lack of adequate training and technical support. Policy interventions through the provision of subsidies, infrastructural development, and improved training programs will be required to overcome these challenges and ensure wider diffusion.

The study shows that there is high potential for improving productivity in agriculture with the use of predictive tools and smart farming technologies in Nigeria. However, these benefits are not fully realized due to several fundamental challenges, one of them being the cost involved in acquiring and distributing the technologies, which is quite high for many farmers to afford. Besides that, many farmers lack the critical capabilities and skills necessary for the successful exploitation of these enhanced technologies. Inadequate infrastructure, marked by a severe deficiency in dependable internet access and weak support services, further hinders the effective exploitation of such technologies. However, the positive impact on productivity noted for users of these technologies underlines their potential, while it also discloses the need for targeted interventions to overcome the barriers at present. The research also points out the urgent need for creating awareness and providing practical training to ensure the adoption and proper implementation of technology. Based on the findings and conclusions derived from this study, the following recommendations are made:

1. There should be subsidies and low-interest loans by the government and financial institutions to decrease the financial load on farmers. This would encourage farmers to a larger extent to invest in predictive tools and smart farming technologies.
2. Government investment in rural infrastructure is highly necessary, especially in improving internet connectivity and providing reliable electricity to make effective use of technological innovations.
3. Comprehensive training programs should be designed and implemented to improve farmers' skills and technical knowledge; this may involve workshops, online courses, and on-field demonstrations.
4. Supportive frameworks by policy makers that foster technology adoption should be developed. This encompasses policy formulation in promoting research and development in agricultural technologies while ensuring incentives are given to the farmers in adopting new innovations.
5. Closing the knowledge gap and hence enhancing adoption can be achieved by creating more awareness of the benefits and use of predictive tools and smart farming technologies through extension services and media campaigns.

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