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ASSESSMENT OF POST-HARVEST LOSSES' INFORMATION NEEDS OF VEGETABLE FARMERS IN BAYELSA STATE, NIGERIA

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Abstract

Post-harvest losses represent a significant challenge for vegetable farmers in Bayelsa State, Nigeria, contributing to reduced income, food insecurity and resources wastage. This study assessed post-harvest losses, information needs of vegetable farmers and evaluates the quantity and monetary value of vegetable losses across three agricultural zones in the State. Data were collected using structured questionnaire and analyzed using descriptive statistics and ANOVA. The findings revealed that the most critical areas of information needs include market access and pricing (x=3.66, SD = 0.54), storage (x=3.55, SD = 0.63), and processing methods (x=3.52, SD = 0.60). Transportation and credit availability were of moderate importance. ANOVA results showed no statistically significant differences in vegetable losses among the three agricultural zones (F = 0.498, p > 0.05), suggesting relatively uniform loss patterns across the zones. However, post-hoc analysis indicates higher average losses in Zone 3. These findings underscore the need for targeted interventions to address key areas of information gaps and infrastructure deficiencies, thereby reducing post-harvest losses and improving livelihoods in Bayelsa State.

Keywords: Post-harvest losses, Information, needs, vegetable

1.0 Introduction

Post-harvest losses (PHL) represent a persistent and pressing challenge in agriculture, particularly for smallholder farmers in developing countries. In Nigeria, specifically in Bayelsa State, the issue is pronounced among vegetable farmers who rely heavily on their yields for income and sustenance. Despite being a critical agricultural hub, the State experiences high rates of food loss due to several interrelated factors. These losses not only threaten food security, but also limit economic growth and sustainable agricultural development.

The primary drivers of PHL in Bayelsa State are both systemic and localized.

Inadequate infrastructure, such as poor storage facilities and inefficient transportation systems, play a significant role. Most farmers lack access to cold storage, resulting in rapid spoilage of highly perishable vegetables in the region's humid climate. Furthermore, limited market access exacerbates the problem. Farmers are often unable to sell their produce promptly due to inadequate market linkages, leaving surplus crop produce vulnerable to decay (Kaothar *et al*., 2022).

Compounding these issues is a critical knowledge gap among farmers regarding post-harvest management strategies. Despite the availability of technologies and practices proven to mitigate losses, many farmers are unaware of their existence or lack the training to implement them effectively. This knowledge deficit is further aggravated by insufficient agricultural extension services, which struggle to reach remote farming communities with the information and support they need.

The economic implications of PHL are significant. For smallholder farmers, losses translate directly into reduced income and increased vulnerability to poverty. At the macroeconomic level, these losses undermine the agricultural sector's contribution to national GDP and food security. Nigeria, already grappling with high rates of hunger and malnutrition, can ill afford to waste up to 50% of its agricultural output. Additionally, the environmental impact of PHL cannot be overlooked. Resources such as water, land, and energy, which are invested in producing food, are wasted when crop produce are lost through post-harvest. This inefficiency contributes to environmental degradation and exacerbates the challenges posed by climate change (Olajide and Olonibua, 2019). Most studies on vegetables in Nigeria have been on postharvest information needs among plantain (Olajide and Olonibua 2019), assessment of post-harvest losses of leafy vegetables among rural farmers in Kano and Jigawa State, (Nigeria Mohammed and Usman, 2023), Post-harvest losses and welfare of tomato farmers in Ogbomosho, Osun State, Nigeria (Adepoju, 2014) and costing postharvest losses in selected leafy vegetable marketing in Lagelu Local Government area of Oyo State, Nigeria (Kaothar *et al*. 2022).

2.0 Objectives of the Study

The broad objective was to assess post-harvest lossess information needs of vegetable farmers in Bayelsa State, Nigeria.

The specific objectives of this study were to:

I. identify post-harvest losses information needs of vegetable farmers.

ii. determine area and level of post-harvest losses information needs by vegetable farmers and

iii determine significant difference in post harvest lossess across 3 zones in Bayelsa State, Nigeria.

The study hypothesized that there is no significant difference in the quantity and monetary value of vegetable lost in Bayelsa State.

3.0 Methodology

Bayelsa State is located in the Southern region of Nigeria, within the heart of the Niger Delta. It lies between latitudes 4°15'N and 5°23'N and longitudes 5°22'E and 6°45'E, encompassing a vast area, characterized by intricate networks of creeks, rivers and mangrove swamps. This unique geography is defined by its proximity to the Atlantic Ocean and its position in a deltaic environment, making it one of the most ecologically significant regions in Nigeria. The State is bordered to the North by Delta and Rivers States, to the West by Delta State, to the East and South by Rivers State, and to the South by the Atlantic Ocean. These neighboring areas influence Bayelsa's economic and social dynamics, particularly its role in the oil and gas sector, due to its rich deposits of crude oil and natural gas (National Population Commission, 2006).

Bayelsa State is composed of eight Local Government Areas: Brass, Ekeremor, Kolokuma/Opokuma, Nembe, Ogbia, Sagbama, Southern Ijaw and Yenagoa. A total of 10 vegetable farmers were randomly selected from nine communities from the three agricultural zones. Data were collected through structured questionnaire and were analyzed using descriptive statistics such mean and standard deviation. While analysis of variance (ANOVA) was used to test the hypothesis.

Model Specification

F-stat = $\frac{\text{Between group mean squares (BGMS)}}{\text{Within group mean squares (WGMS)}}$

Decision rule was with a computed value of F-test (ANOVA) greater than the tabulated F-value at 5% level of significance; we rejected null hypothesis (H_o) and accepted the alternative.

4.0 Results and Discussion

4.1 The post-harvest losses information needs by vegetable farmers in Bayelsa State, Nigeria

Table 1 reveals that the highest-ranked need was farmers' willingness to adopt improved methods for harvesting and post-harvest handling, ($\bar{x}$= 3.6; SD = 0.66). This indicates that farmers are open to learning and implementing better practices, aligning with previous findings that highlight the role of behavior change in reducing agricultural losses (Osunde & Onifade, 2021). Participation in training programs on post-harvest management followed closely ($\bar{x}$= 3.5; SD = 0.70), emphasizing the necessity of capacity-building initiatives to improve farmers' knowledge and skills.

Awareness of post-harvest practices ($\bar{x}$= 3.4, SD = 0.78), further underscoring the need for education about storage, handling, and transportation. Environmental factors like temperature, humidity, and rainfall had ($\bar{x}$= 3.3; SD = 0.74), consistent with studies on the impact of climatic variables on produce spoilage (Adebayo et al., 2023). Table 1 also shows that adopting appropriate packaging materials was one of the information needs of vegetable farmers (x= 3.2; SD = 0.73), highlighting the importance of modern storage solutions in minimizing mechanical and environmental damage during transportation.

Conversely, the lowest-ranked needs included access to reliable markets ($\bar{x}$= 2.7, SD = 0.94) and availability of funds for investing in post-harvest technologies ($\bar{x}$= 2.6, SD = 1.02). These findings suggest systemic issues such as limited market access and financial constraints that hinder farmers' ability to mitigate losses effectively. The relatively lower mean score for transportation efficiency ($\bar{x}$= 2.8, SD = 0.88) reflects the ongoing challenges of poor road infrastructure and logistics in the region, which exacerbate delays and contribute to spoilage.

This study reinforces the criticality of integrating technical training with policy interventions to support farmers. Strengthened extension services, affordable financing options, and digital platforms for market access are recommended to address the highlighted gaps. The alignment of these findings with earlier research underscores the multifaceted nature of post-harvest losses and the need for a holistic approach to their reduction (Eze & Obi, 2023).

Table 1: The post-harvest losses information needs of vegetable farmers in Bayelsa State, Nigeria (n=90)

Variables	Mean	SD
Volume of losses: percentage or quantity of vegetables lost after harvest	3.1	0.85
Awareness of post-harvest practices: farmers' understanding of handling, storage, and transportation techniques	3.4	0.78
Availability of extension services, digital platforms, farmer cooperatives	3.0	0.82
Efficiency of transportation networks to reduce delays	2.8	0.88
Adoption of appropriate packaging materials reduce damage	3.2	0.73
Access to reliable markets to sell produce promptly	2.7	0.94
Availability of funds for investing in post-harvest technologies or solutions	2.6	1.02
Participation in training progams on post-harvest management	3.5	0.70
Temperature, humidity and rainfall on vegetable spoilage	3.3	0.74
Use of climate-smart practices to minimize losses	3.1	0.77
Willingness to adopt improved methods for harvesting and post-harvest handling	3.6	0.66
Grand mean	**31**	
Decision mean cut-off point	**2.5**	

Source: Field Survey (2024). SD: Standard deviation.

4.2 Area and level of post-harvest losses information needs by vegetable farmers

Table 2 highlights the various areas, where vegetable farmers in Bayelsa State, Nigeria, face significant information gaps in managing post-harvest losses. Among the five variables, "Market/market price" stands out with the highest mean score of 3.66 (SD = 0.54), which emphasizes the critical importance of market-related information for vegetable farmers. Farmers need to better understand market dynamics, including pricing, demand, and how to navigate the complexities of accessing profitable markets. This need for market information aligns with the findings of Olawuyi *et al*. (2021), who reported that market inefficiencies and poor market access are key drivers of post-harvest losses in developing economies.

Following closely, the areas of "Storage" ($\bar{x}$= 3.55, SD = 0.63) and "Processing" ($\bar{x}$= 3.52, SD = 0.60) are also prioritized by the farmers. Proper storage methods and effective processing techniques are critical in reducing post-harvest losses and preserving vegetable quality. The moderate but consistent demand for information in these areas underscores the need for improved technologies and training for farmers. Storage

practices, such as the use of appropriate containers and controlled environments, can reduce spoilage and wastage, a point highlighted by Akinola (2019). Likewise, processing options such as drying, freezing, or value-added products can help extend the shelf life of vegetables and improve their market value (Nweke *et al*., 2022).

The "Transportation" variable ($\bar{x}$= 3.30, SD = 0.71) also receives a moderate level of importance, signaling the necessity for farmers to be informed about efficient transportation methods that minimize damage and spoilage during the movement of vegetables to markets. This finding supports the argument of Kanu *et al.* (2023), who noted that inadequate transportation infrastructure contributes significantly to post-harvest losses in many regions, especially in rural areas where access to modern logistics is limited.

Interestingly, "Credit availability" shows the lowest information need ($\bar{x}$= 2.88, SD = 0.96), though still above the decision mean cut-off point of 2.5. While credit access remains important, it appears that vegetable farmers prioritize other factors, such as storage, market access, and transportation, as more immediate needs for reducing losses. This finding aligns with the observation made by Eze *et al*. (2020), who found that while credit facilities could enhance farmers' ability to invest in post-harvest management, it is often the lack of technical knowledge and infrastructure that most directly affects post-harvest outcomes.

The grand mean of 3.35 indicates that, on the whole, vegetable farmers in Bayelsa State have a moderate to high level of information needs in post-harvest management, particularly regarding market access, storage, and processing techniques. This suggests that providing comprehensive educational programs, extension services, and access to modern farming tools and techniques could significantly reduce post-harvest losses. Moreover, it highlights the need for policymakers to focus on addressing these gaps by developing targeted strategies that enhance farmers' knowledge and access to critical information.

Table 2: area and level of post -harvest losses information needs by vegetable farmers

variables	Mean	SD
Storage	3.55	0.63
Processing	3.52	0.60
Transportation	3.30	0.71
Market/market price	3.66	0.54
Credit availability	2.88	0.96
Grand mean	3.35	
Decision mean cut -off point	2.5	

Source: Field Survey Data (2024). SD: Standard deviation.

4.3 Difference in the quantity and monetary value of vegetable lost in Bayelsa State.

Table 3 presents the results of an analysis of variance (ANOVA) comparing the difference in the quantity of vegetables lost in the three agricultural zones of Bayelsa State, Nigeria. The ANOVA test reveals a sum of squares of 621.267 between groups, and 54,216.833 within groups. The mean square for the between-group variance is 310.633, while the mean square for within-group variance is 623.182. The calculated F-value is 0.498. Given that the F-value is below the critical value (typically around 3.0 for significance at a 5% level), we conclude that there are no statistically significant differences in the quantity of vegetables lost between the three agricultural zones. This suggests that the post-harvest losses in vegetables may be relatively uniform across the zones, or that other factors not accounted for in this analysis may be influencing the losses.

In line with findings from previous studies on post-harvest losses in Nigeria, which suggest that environmental, economic, and infrastructural factors often contribute to similar loss patterns (Akpan *et al*., 2020; Ogundele *et al*., 2022), the results in Bayelsa State may reflect a broader trend. However, further research could explore other variables, such as farming practices and storage facilities, to better understand the underlying causes of post-harvest losses.

Table 3: Differencein the quantity of vegetable lost in the three agricultural zone

	Sum of Squares	Degree of freedom	Mean Square	F-value
Between Groups	621.267	2	310.633	0.498
Within Groups	54216.833	87	623.182	

Source: Field Survey, 2024

In the study on post-harvest losses management strategies among vegetable farmers in Bayelsa State, Nigeria, Table 3 presents an analysis of variance (ANOVA) to assess the differences in the quantity of vegetable lost across the three agricultural zones. The results show that the F-value (0.498) is not significant at the 0.05 level, indicating no statistically significant difference in the quantity of vegetable losses between the zones ($DF2, 87) = 0.498, p > 0.05$).

However, Table 4 provides a post-hoc analysis of the quantity of vegetable lost in the three agricultural zones, showing the mean quantities of losses for each zone: Zone 1 (31.73), Zone 2 (34.80), and Zone 3 (38.17). Despite the lack of statistical significance in the ANOVA, the post-hoc results suggest that Zone 3 experiences the highest average losses, followed by Zone 2, and Zone 1 with the least losses.

This combination of results from the ANOVA (Table 3) and post-hoc tests (Table 4) implies that, while the differences in vegetable losses are not statistically significant overall, there are observable trends in the quantity of losses across the zones. These trends can guide further investigations into local factors affecting post-harvest losses in each zone.

Table 4 post-hoc test on quantity of vegetable lost in the three agricultural zones of Bayelsa State.

Agricultural zones	Post-hoc
Zone 1	31.73^{a}
Zone 2	34.80^{a}
Zone 3	38.17^{a}

Source: Field Survey, 2024

5.0 Conclusion and Recommendations

5.1 Conclusion

The study highlights that vegetable farmers in Bayelsa State have moderate to high levels of information needs regarding post-harvest management, particularly in market access, storage, and processing. Despite a lack of statistically significant difference in PHL among the agricultural zones, observable trends suggest that Zone 3 experiences the highest losses. These findings point to systemic challenges such as inadequate infrastructure, poor market access, and limited farmer training as the main contributors to PHL. Addressing these issues is crucial for reducing vegetable losses, enhancing farmers' incomes, and ensuring food security in the State.

5.2 Recommendations

Based on the findings of this study, the following recommendations were made:

1. Enhanced Agricultural Extension Services: Strengthen the reach of extension programs to educate farmers on effective post-harvest management strategies, including proper storage, transportation, and processing techniques.
2. Infrastructure Development: Invest in cold storage facilities, efficient transportation systems, and market linkages to reduce spoilage and improve farmers' access to profitable markets.
3. Market Information Systems: Establish platforms or digital tools that provide real-time market pricing, demand trends, and distribution networks to farmers.
4. Capacity-Building Programs: Organize regular training workshops on value addition and processing methods, empowering farmers to create higher-value products and reduce wastage.
5. Policy and Financial Support: Develop policies and grant schemes that improve credit access for smallholder farmers, enabling them to invest in modern post-harvest technologies and infrastructure.

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FACTORS INFLUENCING FOOD SECURITY AMONG SMALL-HOLDER YAM FARMERS IN ZANGON-KATAF LOCAL GOVERNMENT AREA OF KADUNA STATE, NIGERIA

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Abstract

Yam (Dioscorea spp.) is an energetic crop in Nigeria, contributing significantly to food security, income generation and cultural identity. Despite its importance, small-holder yam farmers in Zangon-Kataf Local Government Area (LGA), Kaduna State, face persistent food insecurity challenges, due to socio-economic, institutional and environmental factors. This study analyzes these factors, focusing on food security indicators like Household Food Insecurity Access Scale (HFIAS) and Food Consumption Score (FCS). The research employs a mixed-methods approach, integrating quantitative survey and qualitative interviews, to explore the socio-economic characteristics of farmers, institutional barriers such as access to credit and extension services, and adaptive strategies like crop diversification and soil management practices. Findings revealed that income, education and farming experience significantly influenced food security, while constraints such as limited access to resources and climate change impacts exacerbate vulnerabilities. The study recommended the role of adaptive farming techniques, including the use of drought-resistant yam varieties and mixed cropping, in mitigating food insecurity. It stresses the need for targeted interventions to enhance institutional support, improve resource access and promote sustainable farming practices among small-holder farmers. Other recommendations include, policy reforms to address gender disparities, expand credit facilities and strengthen agricultural extension services to build resilience against socio-economic and environmental challenges.

Keywords: Factors**,** Influencing**,**Food, Security, Small-holder Yam Farmers.

1.0 Introduction

Yam (*Dioscorea spp*.) is an energetic crop in Nigeria, recognized for its significant contributions to food security, income generation and cultural identity. As one of the largest yam-producing nations, Nigeria's agricultural sector heavily relies on the productivity of small-holder farmers, who account for the majority of yam production. These farmers are pivotal in meeting the growing food demand in rural and urban areas alike. Historically, yam cultivation has been integral to the livelihoods of many communities in Zangon-Kataf Local Government Area (LGA), Kaduna State. The area's agricultural heritage is shaped by traditional farming methods, cultural practices and reliance on small-holder systems. However, evolving challenges have made it imperative to investigate the factors influencing food security among yam farmers.

Food security, defined as the availability, accessibility and utilization of food, is a pressing issue in many rural communities. Despite the strategic importance of yam farming, many small-holder farmers in Zangon-Kataf LGA face constraints such as limited access to credit, extension services and improved agricultural inputs. These challenges, compounded by socio-economic and institutional factors, affect productivity, income levels and overall food security. Additionally, climate change and fluctuating market conditions exacerbate vulnerabilities, making it critical to explore adaptive strategies that enhance food systems and reduce household food insecurity.

1.1 Statement of the Problem

Food insecurity remains a significant challenge in Nigeria, particularly among rural households who dependent on subsistance agriculture. Despite Zangon-Kataf LGA being a major yam-producing region, a considerable proportion of its small-holder yam

farmers continue to face food insecurity. The reliance on traditional farming methods, low productivity and socio-economic disparities exacerbate this issue, threatening the livelihoods and nutritional well-being of the local population (Nkeng *et al*., 2019; Ezeaku & Akpan, 2018).

Socio-economic factors such as age, gender, education, farm size and income have been identified as critical determinants of food security among small-holder farmers. Institutional constraints, including inadequate access to extension services, credit facilities and market linkages, further undermine the capacity of yam farmers to enhance productivity and adopt sustainable practices (National Population Commission, 2006). These barriers hinder adoption of essential adaptation strategies such as early-maturing and drought-resistant yam varieties, mixed cropping and improved soil management practices that are critical for building resilience against climate change and other shocks.

While existing studies highlight the importance of adaptive farming techniques in addressing food insecurity, there is limited research on how these strategies are implemented by small-holder yam farmers in Zangon-Kataf LGA. Additionally, the interplay between socio-economic, institutional and environmental factors influencing food security in the area remains underexplored. This research seeks to fill this gap by analysing the factors influencing food security among small-holder yam farmers, with the aim of formulating policies and interventions tailored to their unique challenges.

2.0 Objectives of the Study

The broad objective was to analyse socio-economic and institutional factors influencing food security among small-holder yam farmers in Zangon-Kataf Local

Government Area of Kaduna State.. The specific objectives were to:

i. describe the socio-economic characteristics of small-holder yam farmers in the study area and

ii. identify factors affecting food security in the study area.

3.0 Research Methodology

3.1 The Study Area

The study was carried out in Zangon-Kataf Local Government Area (LGA) with the headquarters at Zonkwa. The area is located between latitudes $9^0 25^/N$ and $10^0 20^/N$ and longitudes $7^0 45^/E$ and $8^0 40^/E$ is bounded by Kajuru L.G.A. in the North, Jama'a in the South, Kachia in the West and Kaura LGA in the East (The Information Division of Zangon-Kataf Secretariat, 1999).

The soil in Zangon-Kataf LGA is predominantly ferruginous tropical soils that is suitable for yam cultivation, but requires fertilizers and organic amendments due to fertility variability. The indigenous population is largely rural, with agriculture being the main source of livelihood. Yam is a major crop, cultivated both for subsistence and commercial purposes. However, small-holder farmers in the area face numerous challenges, including limited access to capital, agricultural inputs and market infrastructure (Ezeaku & Akpan, 2018). The impacts of climate change such as altered rainfall patterns, increased temperatures and more frequent extreme weather events, affect crop yields and food security (Nkeng *et al*., 2019). This study is significant as it provides perceptions into how small-holder yam farmers in Zangon-Kataf LGA are adapting their agricultural practices in response to these challenges.

3.2 Population of the Study

Zangon-Kataf LGA has a population of approximately 318,991 with a significant portion engaged in agriculture (NPC, 2006). The specific population for this study includes small-holder yam farmers, totaling 2,193 individuals. Based on the sample size determination formula by Krejcie and Morgan (1970), a sample size of 384 was deemed suitable for a 95% confidence level with a 5% margin of error. However, due to the focus on yam farming, the study focused on 2,193 yam farmers in the area.

3.2.1 Sample size and Sampling Techniques

A multi-stage sampling technique was used to select respondents from the study area. The first stage involved purposively selecting Zangon Kataf LGA due to the high concentration of yam farmers. In the second stage, two chiefdoms – Atyap and Bajju were selected using simple random sampling. Within these chiefdoms, two districts were purposively chosen from Atyap and randomly selected from Bajju. The final stage involved selecting two villages from each district, resulting in eight villages being selected for the study. This approach ensures that both the diversity of farming practices and the impact of conflict (particularly in Atyap) on farming activities are adequately captured.

The purposive sampling technique adopted in Atyap chiefdom was because; the researcher relied on personal judgment with the perception that yam farmers as a result of persistent attacks in many of the Atyap villages must have been displaced, only yam farmers in villages relatively free from the attacks were selected. The adoption of the simple random sampling in Bajju chiefdom was because; the chiefdom did not experience incessant attacks as the case with the Atyap chiefdom. The final stage was

random selection from the sampling frame of 2,193 to give a sample size of 219 farmers, that is, 10% of the population or sample frame.

3.2.2 Data Collection Methods

The study employed both quantitative and qualitative methods. Quantitative data were collected through surveys, while qualitative perceptions were gathered through semi-structured interviews with farmers and agricultural experts. This mixed approach allowed for a complete analysis of adaptive practices and the challenges faced by farmers in the context of climate change.

3.2.3 Data Analysis Techniques

The data for this study were analysed using both descriptive and inferential statistics Multivariate probit regression model was used to determine factors influencing adoption of adaptation strategies. Tesfaye and Nayak (2022) buttressed the formula of the multivariate probit model for the observations as follows:

$$Y_i = 1 \text{ if } \beta_i x + \varepsilon_i > 0 \ldots\ldots\ldots\

by Adebayo (2020), who reported similar findings in sub-Saharan Africa. The limited participation of younger farmers may result from rural-urban migration or their preference for non-agricultural livelihoods.

Table 1 also reveals that yam farming is predominantly male-dominated (86.76%), Agboola (2019) similarly observed that socio-cultural norms and land ownership constraints limit women's participation in agriculture in Nigeria. This under representation of women (13.24%) highlights the need for policies that address gender disparities in access to land, credit and inputs.

Majority (63.93%) of the respondents 10–15 years of farming experience, indicating that yam farming is sustained by seasoned participants. Experience contributes to improved productivity through better adaptation to environmental conditions and refined farming techniques. As noted by Oni and Yusuf (2021), experienced farmers are more likely to achieve higher yields and adopt sustainable practices. Medium-sized households (10–15 members) dominate the study area, comprising 38.36% of the sample, with 64.84% of farmers relying on household labour. This reflects the prevalence of family labour in small-holder farming, as financial constraints limit the hiring of external workers. Reliance on household labour may hinder productivity during peak farming periods, as also noted by Oni and Yusuf (2021).

Table 1 further reveals that 61.18% of the respondents had having tertiary education. This is advantageous, as educated farmers are more likely to adopt innovative practices and access marketing information. Ajani (2018) emphasized that literacy enhances productivity and adaptation to agricultural innovations. The majority of farmers (86.3%) operated on farms smaller than 4 hectares, this limiting production

capacity and discouraging mechanized farming. This finding supports Ayinde (2021) who highlighted that, small-holder farmers had been facing structural constraints that hinder scaling up.

Despite small farm sizes, yam farming appears profitable with 64.37% earning more than ₦1,500,000 annually. However, 13.25% of farmers earned less than ₦400,000 indicating disparities likely driven by variations in resource access, farm size and market opportunities. Only 17.81% of respondents rely solely on farming, while others supplement their income through activities such as artisanal work (26.48%), civil service (21.92%) and business (25.11%). This diversification stresses the importance of

Table 1: Socio-economic Characteristics of Yam Farmers (n = 219)

Variables	Percentage (%)
Age (years)	
<35	7.77
35-55	54.7
>55	37.53
Gender	
Male	86.76
Female	13.24
Years of farming experience	20.53
<10	63.93
10-15	15.55
>16	
Household size	
<10	38.36
10-15	31.04
>16	30.6
Levels of Education	
Non formal education	0.46
Primary	1.37
Secondary	36.99
Tertiary	61.18
Farm size (ha)	
<4	86.3
4-6	13.24
>6	0.46
>1500000	13.25
	22.38
	64.37
Occupation	
Farmer	17.81
Artisan	26.48
Civil servant	21.92
Business	25.11
Others	8.68

Source: Field Survey (2025).

4.2 Factors influencing food security status among small-holder yam farmers

According to Table 2, the income of yam farmers was identified as a determinant of food security, with a statistically significant and positive impact on the Food Consumption Score (FCS) ($p = 0.000$). This suggests that households with higher incomes are better positioned to access diverse and nutritious food, leading to improved food security. These finding agrees consistent with Akinyele (2020), who emphasized the role of income in mitigating food insecurity. Higher income levels enable households to buffer against price fluctuations and maintain consistent access to essential food supplies.

Farm size exhibited a significant positive effect on the FCS ($p = 0.001$). Larger land holdings allow farmers to diversify crops that not only increase food availability but also enhance dietary diversity. This corroborates findings by Asiedu and Sartie (2010), who highlighted the benefits of larger farms in improving productivity and food security.

Access to extension services positively influenced food security ($p = 0.062$), as these services equip farmers with knowledge on innovative farming techniques and climate adaptation strategies. Ahmed *et al*. (2021) also noted the pivotal role of extension services in improving agricultural productivity, thereby enhancing food security outcomes.

Age was found to have a small but negative effect on food access (HFIAS coefficient = - 0.027, $p = 0.202$). This could be attributed to reduced physical ability and reluctance of older farmers to adopt modern farming practices. Adebayo (2020) highlighted similar generational differences in adoption of agricultural innovations.

Larger household sizes negatively impacted food access (HFIAS coefficient = - 0.037). This is likely due to the increased demand for food resources in larger households, as also noted by Akinyele (2020). Households with more members face greater challenges in ensuring sufficient food for all, especially when reliant on limited income sources.

Contrary to expectations, access to credit showed a negative association with household food access (HFIAS coefficient = - 0.214). This might be explained by the diversion of credit resources for non-food-related purposes or repayment obligations, which could temporarily reduce food availability. This findings agrees by Bala *et al*. (2019), who reported that credit often supports long-term investments rather than immediate food needs.

Adopting early-maturing crop varieties negatively affected food access (HFIAS coefficient = - 0.872) but had a positive impact on the FCS. Initial adoption costs and the challenges of transitioning to new systems may explain the short-term negative effects. Over time, however, early-maturing varieties contribute to better yields and improved dietary diversity, as noted by Ayankanmi *et al*. (2021).

Mixed cropping and changing ridges showed mixed effects on food security. These strategies improved FCS but did not significantly affect household food access. The labor-intensive nature of these practices could can strain immediate food access, while contributing to long-term productivity (Altieri & Nicholls, 2017).

Although education did not show a direct significant effect on food security, it was positively correlated with adopting climate adaptation strategies. Educated farmers

are more likely to apply effective farming techniques, indirectly enhancing food security (Ajani, 2018). Similarly, access to weather information, while not statistically significant, helps farmers make informed decisions, reducing risks of crop failure (Aggarwal *et al*., 2018).

Table 2: Factors influencing small-holder yam farmers' food security status (n = 219)

Table 2: Factors influencing small -holder yam farmers' food security status (n = 219)

	Household Food Insecurity Access Scale (HFIAS)			Food Consumption Score (FCS)		
ıriables	Coefficient	Std. error	P-value	Coefficient	Std. error	P-value
ge	-0.027	0.021	0.202	0.023	0.060	0.702
ender	-0.603	0.505	0.233	-4.529	1.416	0.002
ears of farming experience	0.028	0.024	0.257	0.109	0.068	0.111
ousehold size	-0.037	0.075	0.267	0.200	0.211	0.343
ousehold labour size	0.167	0.097	0.086	-0.607	0.272	0.027
lucational Qualification	-0.134	0.095	0.160	0.625	0.267	0.020
rm size	-0.354	0.254	0.165	0.495	0.713	0.488
come per annum	0.000	0.000	0.306	0.000	0.000	0.193
cess to extension service	-0.259	0.505	0.609	3.036	1.417	0.033
cess to credit	0.214	0.474	0.652	-0.186	1.329	0.889
cess to weather	0.703	0.554	0.206	0.701	1.553	0.652
formation	-0.883	0.564	0.119	-1.858	1.581	0.241
cess to input subsidy	-0.529	0.436	0.227	2.100	1.225	0.088
embership in cooperative	-0.872	0.476	0.068	-0.205	1.336	0.878
dapt to early maturing	-0.777	0.462	0.094	1.574	1.297	0.226
dapt to drought	-1.835	0.583	0.002	3.957	1.635	0.016
dapt to change in ridges	1.058	0.564	0.062	1.332	1.581	0.401
dapt to mix cropping	0.753	0.453	0.098	-1.727	1.270	0.175
dapt to crop rotation	9.297	1.780	0.000	32.497	4.994	0.000
onstant	219			219		
umber of observations	0.000			0.000		
ob>F	0.441			0.385		
	0.391			0.3301		
djusted R^2						

Source: Field Survey (2025).

5.0 Conclusion and Recommendations

5.1 Conclusion

The research highlights the complex interplay of socio-economic, institutional and adaptive factors that influence food security among small-holder yam farmers in Zangon-Kataf Local Government Area, Kaduna State. Key findings indicate that income, farm size, access to extension services and adoption of adaptive strategies such as early-maturing yam varieties and mixed cropping are important factors shaping food security outcomes. Higher income levels and larger farm sizes were positively associated with improved food security, particularly in terms of food consumption. Conversely, household size and access to credit were found to negatively impact food security, stressing the challenges faced by larger households and the misalignment of credit use with immediate food needs.

Despite the significant role of adaptive practices like early-maturing varieties and mixed cropping in improving productivity, their short-term negative effects on food access suggest the need for more complete support for farmers transitioning to these strategies. The study also stresses the importance of education, with educated farmers showing a greater propensity to adopt climate adaptation strategies that indirectly contribute to food security. The research provides a clear indication of the need for more tailored interventions that address the socio-economic and institutional barriers faced by smallholder farmers in ZLGA, while also promoting the adoption of climate-resilient farming practices.

5.2 Recommendations

Based on the findings, the following recommendations were made:

1. **Extension agents should** improve accessibility and utilization of credit facilities for small-holder farmers, ensuring that loans are used effectively for farming inputs and not diverted for non-agricultural purposes. Additionally, expanding extension services to provide farmers with updated knowledge on adaptive farming techniques, climate resilience and market trends is crucial for improving food security.
2. **Social workers should a**ddress gender disparities in agriculture by facilitating women's access to land, credit and extension services. Gender-sensitive policies should be implemented to encourage greater female participation in yam farming that contributes to more balanced productivity and food security outcomes.
3. Early-maturing and drought-resistant yam varieties, as well as mixed cropping and other climate-smart practices, should be promoted through farmer training and subsidized input schemes. Support mechanisms to mitigate the initial challenges of adopting these strategies will be key to improving their long-term impact on food security.
4. While education alone did not show a direct significant effect on food security, it was positively correlated with the adoption of climate adaptation strategies. Continued educational outreach, especially for younger farmers, should be prioritized to foster greater innovation and resilience in the farming community.
5. Given the significant role of off-farm income in supporting household food security, efforts should be made to diversify income-generating activities for rural households, including promoting agribusiness, artisanal work and small-scale industries.

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AN OVERVIEW OF EMERGING TRENDS IN AGRICULTURAL TECHNOLOGY AND INNOVATION SYSTEMS IN NIGERIA

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Abstract

Agricultural technology represents a transformative force, integrating scientific knowledge, tools and innovations to enhance productivity, efficiency and sustainability within farming systems. From its historical roots in traditional practices to the mechanized and digital advancements of today, the evolution of agricultural technology has reshaped how food is cultivated, processed and distributed. Mechanized tools, biotechnology and digital platforms have significantly improved yields, resource management, and resilience, contributing to food security and economic growth. However, challenges such as cost barriers, infrastructural deficits and cultural resistance hinder equitable access, particularly for smallholder farmers. Institutions such as the International Institute of Tropical Agriculture (IITA) and River Basin Development Authorities (RBDA) have played pivotal roles in promoting research and innovation in Nigeria. Genetically modified crops like Bt cotton and digital tools like Farm-Crowdy exemplify the sector's potential to revolutionize farming practices. Yet, the uneven distribution of technology, especially in rural areas, highlights the need for inclusive policies, robust extension services and infrastructure development to bridge gaps in adoption and diffusion. Empowering women and youth in agriculture through labour-saving technologies and tailored interventions is critical for achieving sustainable and inclusive growth. Digital tools and precision agriculture further enable data-driven decision-making, optimizing inputs and reducing environmental impacts. Climate-smart technologies such as drought-resistant crops and renewable energy solutions, address sustainability and climate change challenges, fostering resilience and reducing operational costs. While agricultural technologies offer immense opportunities for improving livelihoods and food security, its full potential can only be

realized through targeted efforts to ensure accessibility, adaptability to indigenous contexts and equitable distribution. By addressing these barriers, agricultural systems could achieve greater productivity, resilience and sustainability, supporting global efforts to combat hunger, poverty and environmental degradation.

Keywords: Overview, Agricultural, Technology, Innovation, Systems.

Agricultural technology encompasses the integration of scientific knowledge, tools and innovations aimed at enhancing productivity, efficiency and sustainability within agricultural systems. These technologies can be broadly categorized into mechanical, biological and chemical innovations, each addressing distinct challenges across the agricultural value chain. Mechanical advancements such as tractors and irrigation systems, alleviate labour-intensive processes, while biological tools like genetic modification and biocontrol improves crop resilience and yields.

Historical evolution of agricultural practices in Nigeria reflects a shift from traditional, labour-intensive methods to adoption of mechanized tools and improved crop varieties introduced during the colonial era (Adebayo and Thompson, 2022). During Post-independence, institutions like the International Institute of Tropical Agriculture (IITA) and River Basin Development Authorities (RBDA) had played significant roles in promoting agricultural research and development (Okonkwo and Ibrahim, 2023). Contemporary agricultural innovations emphasize digital and precision technologies focusing on sustainability.

Science and technology continue to revolutionize agriculture through breakthroughs in biotechnology, mechanization and digital tools. For example, genetically modified crops such as Bt cotton have demonstrated significant yield improvements and reduced pesticide use in several African countries, including Nigeria

(Hassan *et al*., 2023). Mechanized tools and irrigation systems have further enhanced productivity and mitigated labour shortages (Martinez and Wong, 2024). Additionally, digital platforms like Farm-Crowdy and Hello Tractor provide Nigerian farmers with access to critical resources, demonstrating the transformative potential of agricultural innovation (Williams and Hassan, 2024).

Despite these advancements, challenges remain, particularly in ensuring equitable access to agricultural technologies among smallholder farmers. High costs, infrastructural deficits and cultural resistance often hinder widespread adoption, stressing the need for policies and programs that address these barriers (Okonkwo and Ibrahim, 2023). Strengthening agricultural extension services and investing in rural infrastructure are crucial for fostering innovation diffusion and improving food security (Doss *et al*., 2023). Agricultural technology serves as a cornerstone for addressing global challenges related to food security, climate change and resource sustainability. By leveraging scientific advancements and promoting equitable access, agricultural systems can achieve greater productivity and resilience, contributing significantly to economic growth and poverty reduction.

2.0 Foundations of Agricultural Technology

Agricultural technology encompasses the application of scientific knowledge, tools and innovations to improve agricultural practices and outputs. It involves application of diverse range of tools, techniques and methodologies aimed at enhancing productivity, efficiency and sustainability of agricultural systems (Johnson and Peters, 2023).

The introduction of improved agricultural practices during the colonial era

marked a significant shift, as mechanized tools, fertilizers and improved crop varieties were introduced.

2.1 Role of Science and Technology in Agriculture

Science and technology serve as the backbone of agricultural advancements, with their contributions extending across multiple domains. Biotechnology has revolutionized agricultural systems by introducing genetically modified crops, which are resistant to pests, disease, and environmental stressors. Advances in molecular biology and genetic engineering have enabled the development of high-yielding and nutrient-rich crop varieties, addressing nutritional deficiencies and food scarcity.

Mechanization represents another cornerstone of agricultural technology. Tractors, harvesters and irrigation systems have alleviated the burden of manual labour and increased efficiency in farm operations. Mechanized systems have been particularly transformative in places with labour shortages, enabling large-scale farming and reducing post-harvest losses (Martinez and Wong, 2024). Despite these advancements, mechanization in Nigeria remains unevenly distributed, with smallholder farmers often lacking access due to cost and infrastructural constraints.

Digital tools, including satellite imagery, geographic information systems (GIS) and mobile applications, are increasingly shaping modern agricultural practices. Precision agriculture, which relies on data analysis and real-time monitoring, allows farmers to optimize resource use and reduce environmental impacts (Williams and Hassan, 2024).

Agricultural technology plays a pivotal role in driving food security, which is a pressing concern in the face of global population growth and climate change. Enhanced

productivity through technology reduces the yield gap and ensures consistent food supply. Kumar and Ahmed (2023) demonstrated that regions adopting advanced agricultural technologies experience a 30 percent increase in crop output compared to traditional practices. Furthermore, these technologies support sustainable practices by minimizing waste, optimizing resource use and mitigating environmental degradation.

The foundations of agricultural technology is deeply rooted in the integration of scientific principles and innovative solutions to address challenges in agricultural systems. By leveraging advancements in biotechnology, mechanization and digital tools, the agricultural sector can achieve greater resilience, productivity and sustainability. However, equitable access and the adaptation of these technologies to local contexts remain critical to ensuring their widespread impact and contribution to food security.

2.2 Agricultural Innovation Systems (AIS)

Agricultural innovation systems (AIS) are complex networks that encompass interplay of diverse actors and processes working collaboratively to foster innovation in agriculture. The components of AIS include research and development (R&D) institutions, agricultural extension services, market systems, financial institutions, and policymaking bodies. Research institutions provide the foundation for developing new technologies through scientific inquiry, extension services act as a bridge between researchers and farmers, ensuring that innovations are disseminated effectively (Hall *et al*., 2022). Market systems influence the adoption of innovations by determining accessibility, affordability and financial institutions enable investments in technology. Policymaking bodies provide the regulatory framework and incentives to encourage innovation adoption, such as subsidies and tax exemptions for agricultural inputs.

Stakeholders in agricultural technology development and dissemination include farmers, researchers, agribusinesses, non-governmental organizations (NGOs) and government agencies. Farmers, as end-users, are pivotal in shaping the success of any innovation through their feedback and adaptability to new techniques. Researchers and developers work on creating technologies that address specific agricultural challenges, agribusinesses facilitate the commercialization and distribution of these technologies. NGOs and international development organizations often focus on capacity-building and awareness campaigns to promote technology adoption among marginalized groups (Spielman and Birner, 2023). Governments play a central role by formulating policies, funding R&D and fostering an enabling environment for innovations.

2.3 Adoption and Diffusion of Agricultural Technologies

Theories of innovation adoption in rural communities, such as Rogers' Diffusion of Innovations theory, provide a framework for understanding how new agricultural technologies are embraced. According to Rogers (2003), adoption process involves five stages: awareness, interest, evaluation, trial and adoption. The rate of adoption varies among farmers and can be categorized into five adopter groups: innovators, early adopters, early majority, late majority, and the laggards. Factors influencing adoption include relative advantage of the innovation, its compatibility with existing practices, simplicity, trialability and observability. For instance, a farmer is more likely to adopt a drought-resistant crop variety if it aligns with their traditional farming practices and demonstrates tangible benefits, such as high yields.

Challenges in technology diffusion among smallholder farmers often stem from structural, cultural and economic barriers. Limited access to credit and financial

resources hinders ability of smallholders to invest in new technologies (Doss *et al*., 2023). Furthermore, lack of infrastructure, such as roads and markets, constrains distribution and accessibility of innovations. Cultural resistance often rooted in traditional practices and beliefs can also slow the acceptance of innovations. Additionally, inadequate extension services result to a gap between technology developers and end-users, leading to poor awareness and lack of understanding of innovations.

2.4 Women and Youths' Perspectives in Agricultural Technology

Empowering women and youths in agriculture through innovative tools and techniques is essential for achieving inclusive and sustainable development. Women play a crucial role in agriculture, particularly in developing countries, where they constitute a significant portion of the agricultural labor force. However, they often face barriers such as limited access to land, credit and technology bias. Targeted interventions such as introduction of labour-saving technologies and gender-sensitive extension services, have shown to enhance productivity and reduce drudgery associated with traditional farming methods (Quisumbing *et al*., 2023). For example, adoption of small-scale mechanized equipment, such as grain threshers, has significantly improved the efficiency of post-harvest processing, particularly for women farmers.

Youths engagement in agriculture is critical to addressing the aging farming population and ensuring sustainability of the sector. Innovations tailored to youths have the potential to attract young people to agriculture. Moreover, training programs and capacity-building initiatives that integrate digital literacy and modern farming techniques can equip youths with the skills needed to thrive in the evolving agricultural

landscape (Proctor and Lucchesi, 2022).

Bridging the digital divide in rural agricultural communities remains a pressing challenge. Digital tools, such as mobile applications, e-commerce platforms and GIS technologies, have the potential to transform agricultural practices, but their impact is limited by uneven access to technology. Rural areas often lack reliable internet connectivity and electricity, making it difficult for farmers to benefit from digital innovations (World Bank, 2023). Addressing this divide requires investments in rural infrastructure, promotion of affordable digital devices and provision of training programs to enhance digital literacy. Adoption and diffusion of agricultural innovations are influenced by a dynamic interplay of systems, stakeholders and social factors. Understanding these elements and addressing the barriers faced by marginalized groups such as women, youth, and smallholder farmers is crucial for fostering equitable and sustainable agricultural development.

3.0 Applications and Impacts of Agricultural Technology

The advent of technology in agriculture has revolutionized agricultural practices by integrating advanced technologies to enhance productivity, efficiency and sustainability. The Internet of Things (IoT), drones and artificial intelligence (AI) are central to this transformation. IoT technologies such as sensors and connected devices enable real-time monitoring of soil conditions, crop health, and weather patterns. These devices provide farmers with precise data that facilitate efficient resource management, such as optimizing irrigation and fertilization schedules (Wolfert *et al*., 2017). Drones, equipped with high-resolution cameras and multispectral imaging are used for crop scouting, mapping and pests detection, significantly reducing the time and labor required

for field assessments. AI-powered tools analyze large datasets to predict yield outcomes, recommend planting schedules and identify disease outbreaks, allowing farmers to make informed decisions and mitigate risks (Zhang *et al*., 2021).

Data-driven decision-making is a cornerstone of smart farming, leveraging analytics and predictive modeling to enhance agricultural productivity. Precision agriculture uses geospatial technologies and machine learning algorithms to customize farming practices based on specific field conditions, maximizing yields while minimizing environmental impact (Gebbers and Adamchuk, 2010). For example, variable-rate application technology adjusts inputs such as seeds and fertilizers according to the needs of different field zones, thereby improving resource efficiency and reducing waste. These innovations empower farmers to achieve high productivity with lower costs, thus contributing to global food security.

3.1 Sustainability and Climate-Smart Technologies

Sustainability and climate adaptation have become critical considerations in modern agriculture, driving the development of climate-smart technologies. These innovations aim to increase agricultural resilience to climate variability, while minimizing greenhouse gas emissions. Practices such as conservation agriculture, agroforestry and crop diversification enhance soil health and reduce erosion, promoting long-term productivity (Lipper *et al*., 2014). Drought-tolerant crop varieties, developed through biotechnology are pivotal for areas prone to water scarcity, enabling farmers to maintain yields despite adverse climatic conditions.

Renewable energy technologies such as solar-powered irrigation systems and biogas plants play a significant role in promoting sustainable farming. Solar irrigation

systems harness renewable energy to provide water for crops, reducing dependency on fossil fuels and ensuring consistent water supply during dry periods (Burney *et al*., 2010). Biogas plants convert agricultural wastes into energy, addressing wastes management issues while providing an alternative energy source for rural households. These innovations not only support environmental sustainability but also reduce operational costs for farmers, enhancing their economic viability.

3.2 Impact of Agricultural Technology on Livelihoods

The impact of agricultural technology on livelihoods is profound, particularly in rural communities where agriculture is the primary source of income. Socioeconomic benefits of technological adoption include increased productivity, high incomes and improved food security. Mechanization, for instance, reduces labor intensity and increases efficiency, allowing farmers to cultivate larger areas and achieve higher yields (Pingali, 2007). Similarly, access to improved seeds and fertilizers has enabled smallholder farmers to boost their production and marketability, contributing to poverty reduction and economic growth.

Success stories from Nigerian farmers highlight the transformative potential of agricultural innovations. For example, adoption of mobile platforms for market access and weather forecasting has empowered farmers in remote areas to make timely decisions and negotiate better prices for their produce (Aker, 2010). Extension services have also, played a crucial role in disseminating information on technologies and building farmer capacity. Programs such as Nigeria's Agricultural Transformation Agenda had focused on enhancing access to inputs, training, and credit, resulting to measurable improvements in productivity and livelihoods (Adesina, 2012).

The integration of digital agriculture, sustainability-oriented innovations and targeted interventions have significantly influenced the agricultural landscape. By addressing critical challenges such as climate change, resource scarcity and market access, these technologies not only enhance productivity, but also contribute to the social and economic empowerment of farming communities.

4.1 Future Directions in Agricultural Technology

Adoption of agricultural technology is significantly influenced by the policy environment, which can either enable or hinder innovations. A supportive policy framework is essential to create an ecosystem where agricultural technologies can thrive. Effective strategies for enabling environment include fostering research and development, providing financial incentives, ensuring equitable access to resources and technologies. For instance, governments can facilitate tax breaks and subsidies for farmers investing in advanced tools and machinery. Furthermore, strengthening intellectual property rights is crucial to encourage private sector innovation and the commercialization of agricultural technologies (Spielman and Birner, 2008).

Public-private partnerships (PPPs) are pivotal in driving agricultural innovations. These partnerships leverage the strengths of both public and private sectors, combining the government's regulatory oversight and infrastructural capabilities with the private sector's expertise, capital and technological innovations. PPPs have been instrumental in initiatives such as providing smallholder farmers with access to improved seeds, fertilizers, and digital tools. For example, in Nigeria, collaborations between government and private entities under programs like the Growth Enhancement Support Scheme (GESS) has enhanced inputs distribution systems, ensuring farmers

receive quality agricultural inputs (Adesina, 2012). PPPs also, play a key role in capacity building, helping farmers to adopt and maximize the benefits of emerging technologies through training and extension services.

Agricultural sector is witnessing transformative changes driven by emerging trends in technology and innovation. These trends include integration of robotics, autonomous systems and block-chain technology into agricultural practices. Robotics and automation have redefined farming operations, enabling precise planting, harvesting, and weeding which have reduced labor costs and increase efficiency (King, 2022). Block-chain technology, on the other hand, offers potential solutions for traceability, ensuring transparency in supply chains, and enhancing food safety by providing detailed records of production and distribution processes (Tripoli and Schmidhuber, 2018).

The potential impact of these trends on agricultural sector is immense. Precision farming and vertical agriculture are set to address challenges such as land scarcity and environmental degradation. These practices, coupled with advancements in synthetic biology, could lead to the development of bioengineered crops with enhanced nutritional profiles and resistance to diseases and pests. Moreover, the growing emphasis on carbon-neutral farming will shape the sector's contribution to mitigating climate change.

Farmers need these technologies, and financial institutions must be incentivized to provide affordable credit to farmers, enabling them to invest in modern technologies. Digital platforms can facilitate this process by providing transparent and efficient means of accessing financial services.

Capacity-building initiatives are another essential component of this roadmap.

Farmers need education and training to adopt and effectively utilize emerging technologies. Collaborative efforts among government agencies, academic institutions and private companies can bridge knowledge gaps and equip farmers with the skills necessary for innovation adoption. Moreover, fostering youths participation in agriculture through technology-driven programs can ensure sustainability of these advancements by engaging the next generation of agricultural practitioners (Olaniyi *et al*., 2015). The future of agricultural technology lies in creating synergistic frameworks that combine policy support, private sector involvement and farmer-centric approaches. By addressing systemic challenges and leveraging emerging innovations, the agricultural sector in Nigeria can achieve sustainable growth, enhance productivity and contribute significantly to food security and economic development.

5.0 Conclusion and Recommendations

5.1 Conclusion

Advancement of agricultural technology stands as a cornerstone for addressing critical challenges in global and local agricultural systems, particularly in the context of food security, environmental sustainability and socioeconomic development. From its historical foundations rooted in traditional practices to its evolution into a diverse array of mechanical, biological and chemical innovations, agricultural technology continues to redefine productivity and resilience in farming communities.

Integration of science and technology into agriculture has propelled the sector towards higher yields, reduced labor intensity and better management of resources.

Innovations such as precision farming, biotechnology and climate-smart practices have enabled farmers to adapt to changing climatic conditions, while ensuring sustainable production. Moreover, adoption and diffusion of these technologies depend on collaborative efforts across agricultural innovation systems, including policymakers, researchers, extension services and the private sector. Addressing barriers such as financial constraints, cultural resistance and the digital divide is critical to ensuring equitable access and maximizing the benefits of these technologies for the stakeholders.

5.2 Recommendations

The impact of agricultural technology extends beyond productivity gains, contributing to improved livelihoods, poverty reduction and food security. By fostering inclusivity, sustainability and economic empowerment, agricultural technologies offer transformative potential to create resilient agricultural systems capable of meeting the demands of a growing population. Looking ahead, the future of agricultural technology hinges on sustained investment in research and development, supportive policy frameworks and adaptation of innovations to local contexts. Bridging gaps in access and ensuring the alignment of technologies with the needs of end-users will be crucial in fostering widespread adoption. As agriculture continues to face dynamic challenges, leveraging the full spectrum of technological advancements will be essential for building a sustainable and equitable agricultural landscape for generations to come.

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