ADOPTION OF CLIMATE-SMART AGRICULTURAL PRACTICES BY CASSAVA FARMERS IN DELTA STATE NIGERIA

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ABSTRACT

The study investigates climate-smart agricultural practices among cassava farmers in Delta State, Nigeria, aiming to understand adoption levels, socioeconomic influencers, and constraints. Among 126 respondents, 65.1% were female, reflecting gender imbalances. Farmers, averaging 45 years, spanned the productive age range (20 to 61 years), with 63.5% completing secondary education. Small farm sizes ($\bar{x}$ = 0.9 hectares) and a mean monthly income of ₦73,016.26 signify diverse economic landscapes. Moderate-to-high adoption rates were observed: weather forecasting ($\bar{x}$ = 2.60), drought-resistant cassava varieties ($\bar{x}$ = 3.28), soil conservation ($\bar{x}$ = 2.98), and crop diversification ($\bar{x}$ = 3.15). Education positively impacted soil conservation adoption (B = 0.234, p = 0.029). Higher incomes correlated with water-efficient irrigation (B = 2.931, p = 0.025), while frequent extension contacts supported adoption (B = 0.987, p = 0.039). Constraints included limited information access ($\bar{x}$ = 3.73), financial barriers ($\bar{x}$ = 3.56), inadequate infrastructure ($\bar{x}$ = 3.21), and pest pressures ($\bar{x}$ = 3.25). Access to credit ($\bar{x}$ = 2.73), research gaps ($\bar{x}$ = 2.89), and limited social capital ($\bar{x}$ = 2.91) were moderate concerns. These findings recommend the need for targeted interventions addressing socioeconomic dynamics to promote climate-smart practices, ensuring sustainable cassava farming in Delta State.

Keywords: *Climate-Smart Agriculture, Cassava Farming, Adoption Levels, Sustainable Practices, Delta State*

1.0 Introduction

Climate change presents a major threat to global food security, with Africa being exceptionally vulnerable to impacts on agricultural systems due to its reliance on smallholder rain-fed farming (Zougmoré, Läderach & Campbell, 2021). Rising temperatures, shifting precipitation patterns, and more frequent extreme weather are negatively affecting crop yields and resilience across sub-Saharan Africa (Leal Filho et al., 2022). Without urgent efforts to adapt farming practices and enhance the climate resilience of food production, climate change could lead to severe hunger, malnutrition and livelihood loss across rural African communities in the coming decades (Mwongera et al., 2017).

Climate-smart agriculture encompasses a wide range of production technologies and risk management strategies for reducing climate-related risks while sustainably increasing productivity, incomes, and the ability to adapt to variable conditions (Steenwerth et al., 2014). Key climate-smart techniques include using drought-tolerant crop varieties, improving soil health through organic matter application, implementing efficient water harvesting and irrigation, diversifying production to reduce risk, and adopting agroforestry systems that incorporate climate resilient trees into farmland (Chukwuka & Omotayo, 2021). Tailoring climate-smart solutions specifically for the dominant smallholder crops and production constraints in a target region is crucial.

Cassava is a climate-resilient, nutritious and commercially important staple crop grown by millions of smallholder farmers across sub-Saharan Africa (Amelework et al., 2021). The crop plays a vital role in income, nutrition and food security for rural households and communities (Ileka et al., 2020). In Delta State of southern Nigeria, cassava serves as the single most important crop for small-scale farmers, the vast majority of whom rely on rain-fed production for their livelihoods (Zougmoré et al., 2021).

However, climate change is increasingly impacting cassava yields and quality through higher temperatures, drought periods, flooding, and the accelerated spread of pests and diseases (Leal Filho et al., 2022). For Nigerian cassava producers who already struggle with low productivity, these mounting climate stresses coupled with minimal resources for adaptation threaten both farmer incomes and the national food supply (Kemi & Olusegun, 2020; Emaziye, 2017). Despite the recognition of these challenges, there is a discernible gap in the existing literature concerning the adoption of climate-smart agricultural practices among cassava farmers in Delta State.

Several studies have highlighted the vulnerability of cassava cultivation to climate change in Nigeria. Kemi and Olusegun (2020) conducted a comprehensive review emphasizing the adverse effects of climate change on cassava yield. Ayanlade et al. (2020) explored the implications of changing rainfall patterns on cassava farming communities, underscoring the need for adaptive strategies. Emaziye (2015) delved into the impact of temperature increases on cassava growth and emphasized the urgency of sustainable agricultural practices. In the face of climate change, innovations such as improved storage technologies, new pesticides and the development of genetically modified crops such as cassava have greatly facilitated agricultural production and supply (Goodluck & Joseph, 2024).

While these studies provide valuable insights into the challenges faced by cassava farmers in Nigeria, a critical gap remains in understanding the adoption dynamics of climate-smart agricultural practices among cassava farmers in Delta State. Specifically, there is a dearth of research elucidating the factors influencing cassava farmers' decisions to adopt or resist climate-smart practices and the consequent impact on the resilience and productivity of cassava farming systems in the region. This gap hinders the formulation of targeted and effective interventions that could enhance the adaptive capacity of cassava farmers facing climatic uncertainties. Therefore, this research seeks to assess the adoption of climate-smart agricultural practices by cassava farmers in Delta State Nigeria.

1.1 Objectives of the study

The specific objectives of the study are to:

i. assess the current level of adoption of climate-smart agricultural practices among cassava farmers in Delta State;
ii. examine the socioeconomic factors influencing cassava farmers' decision to adopt climate-smart agricultural practices; and
iii. identify the constraints faced by cassava farmers in the use climate-smart agricultural practices in the study area.

2.0 METHODOLOGY

2.1 Study area

The study focuses on Delta State, Nigeria, as it pertains to the adoption of climate-smart agricultural practices among cassava farmers. Delta State is particularly susceptible to the impacts of climate change, making it an ideal location for investigating how farmers respond to these challenges. The region's predominantly agricultural economy, with cassava being a staple crop, underscores the relevance of understanding the adoption of climate-smart practices in this context (Ebewore & Okedo-Okojie, 2016). Furthermore, Ebewore and Okedo-Okojie (2016) reported that Delta State is characterized by diverse agroecological zones, which influence farming practices and vulnerability to climate change. This geographic variability within the State offers a rich landscape for exploring the nuanced factors affecting the adoption of climate-smart agricultural practices.

2.2 Sampling technique and sample size

A non-systematic sampling approach was employed in a multi-stage fashion. In the initial stage, three agricultural zones, namely Delta South, Delta North, and Delta Central, were selected. Subsequently, two Local Government Areas (LGAs) were chosen from each of these zones, specifically Isoko North, Bomadi, Ethiope West, Ughelli Central, Ukwuani, and Ika South. A total of eighteen communities were selected from each LGA. Utilizing the list of cassava farmers provided by the Delta Agricultural and Rural Development Authority (DARDA) extension agents, seven farmers were randomly chosen from each of the specified communities. This process resulted in a total of one hundred and twenty-six (126) respondents, who participated in the study by responding to a standardized questionnaire.

2.3 Data collection and analysis

Primary data were collected with the aid of structured questionnaire. Data were analysed through the use of descriptive statistics such as frequency, percentage and mean, multinomial logistics regression model and ordinary least square (OLS) regression model.

The multinomial logistics regression model is specified as:

$$\log\left(\frac{P(CSA_i)}{P(Ref)}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots \beta_9 X_9) + e_i \ldots\ldots (1)$$

Where:

$P(CSA_i)$ = Probability of adopting Climate Smart Agriculture (Adoption of weather forecasting = 1; Adoption of drought-resistant varieties = 2; Adoption of soil conservation = 3; Adoption of water-efficient irrigation = 4; Adoption of crop diversification = 5)

P(Ref) = Probability of being in the reference category

X_1 = Gender (male = 1; female = 0)

X_2 = Age (in years)

X_3 = Marital status (single = 1; married =2, divorced = 3 and widowed = 4)

X_4 = Educational level (No formal = 1; Primary = 2; Secondary = 3; Tertiary = 4

X_5 = Farming experience (years)

X_6 = Farm size (Hectare)

X_7 = Income (amount in ₦)

X_8 = Membership of association (yes = 1; No = 0)

X_9 = Extension visits (Non = 1; Once = 2; Twice = 3; More than twice = 4)

$\beta_1 - \beta_9$ = regression coefficients

β_0 = Constant

e_i = error term

3.0 RESULTS AND DISCUSSIONS

3.1 Socioeconomic Characteristics

Gender Distribution: The gender distribution among cassava farmers in Delta State, as indicated in Table 1, unveils a notable gender imbalance with 65.1% of the farmers being female and 34.9% male. This gender disparity aligns with the study of Akoroda (2012) where women play a substantial role in cassava cultivation. Understanding such gender dynamics is critical for the effective design and implementation of climate-smart agricultural interventions. Research suggests that gender-specific roles, access to resources, and decision-making power can significantly influence the adoption of sustainable practices (Ouessar et al., 2021). Consequently, any initiatives aimed at promoting climate-smart agricultural practices in Delta State should be sensitive to the distinct needs and challenges faced by female cassava farmers, acknowledging their pivotal role in the agricultural landscape.

Age: The majority falls within the productive age range of 20 to 61 years, with 31.0% between 20 and 40 years and 32.5% between 41 and 61 years. This distribution suggests a dynamic and potentially innovative farming population. The mean age of 45 years indicates a mature group of farmers who bring a wealth of experience to agricultural practices. Amafade, Ofuoku, Ovharhe & Eromedoghene., (2022) and Hirwa et al., (2022) noted that while younger farmers may be more open to new technologies and innovations, make logical decisions and have time to build their reputation in the community, active and better risk takers, the older farmers may draw on traditional knowledge. Hence, climate-smart agricultural interventions should consider this diversity in age groups, tailoring strategies to harness the strengths and address the specific challenges faced by farmers at different stages of life.

Marital Status: The result in Table 1 revealed a significant portion of farmers are married (42.9%), it is crucial to acknowledge the presence of diverse marital statuses within the sample. The 19.0% who are divorced and the 10.3% who are widowed collectively account for nearly 30% of the respondents. This demographic characteristic is particularly significant in the context of climate-smart agricultural interventions, as it introduces nuances in resource availability and decision-making dynamics. According to Otekunrin and Sawicka (2019), married farmers may have access to shared resources and joint decision-making, potentially influencing the adoption of sustainable practices. On the other hand, divorced or widowed farmers might face distinct challenges, such as managing farms independently or dealing with limited access to certain resources.

Level of Education: According to the result in Table 1, majority of farmers (63.5%) have completed secondary education, indicating a moderate level of formal education within the sample. According to a study by Ojo and Aransiola (2019), education plays a pivotal role in enhancing farmers' capacity to understand and implement innovative farming techniques. Those with higher educational levels may exhibit greater receptivity to new technologies, while those with lower levels might benefit from targeted and simplified extension services. This is also in line with Amafade et al (2022) who noted that educated farmers tend to have a good attitude towards welcoming new innovation and development activities. Incorporating educational components into extension programs can empower farmers with the knowledge and skills necessary for effective adoption of climate-smart practices, ultimately contributing to increased agricultural resilience and sustainability.

Farm Size: The study revealed a mean farm size of 0.9 hectares. This observation underscores the prevalence of smallholder farming systems, a common characteristic in many developing agricultural economies. Small-scale farmers often face unique challenges in adopting climate-smart agricultural practices due to limited resources and land constraints (Forum for Agricultural Research in Africa (FARA), 2015). To enhance the effectiveness of climate-smart interventions, it becomes imperative to tailor strategies that specifically address the needs and limitations of smallholder farmers. Implementing resource-efficient and scalable practices, such as agroforestry and intercropping, could be explored to maximize productivity within the constraints of limited land size. Additionally, fostering community-based initiatives and cooperative farming models may provide opportunities for small-scale farmers to collectively adopt and benefit from climate-smart practices, reinforcing the importance of context-specific strategies for sustainable agricultural development (FARA, 2015).

Farming Experience: The result of the distribution of farming experience among cassava farmers in Delta State revealed an average farming experience of 10 years. About 42.9% had 6-10 years of experience. This cohort represents a crucial segment in the agricultural landscape, as they possess a balanced mix of traditional knowledge and exposure to evolving agricultural practices. According to Otekunrin and Sawicka (2019), farmers with 6-10 years of experience are often well-acquainted with the local nuances of cassava cultivation, making them potential influencers within their communities. Leveraging the expertise of this group can prove instrumental in disseminating information about climate-smart agricultural practices. Additionally, their intermediate level of experience positions them as key adopters who may readily embrace innovations, provided they align with their accumulated knowledge and observed outcomes (Sennuga, Fadiji and Thaddeus (2020). As such, targeted extension services and capacity-building initiatives for this demographic can play a pivotal role in accelerating the adoption of climate-smart practices, ensuring a sustainable transition that amalgamates traditional wisdom with contemporary agricultural advancements.

Farm Monthly Income: The mean farm monthly income of ₦73,016.26 sheds light on the economic landscape of cassava farming in Delta State. This financial metric is crucial in understanding the potential challenges and opportunities associated with the adoption of climate-smart agricultural practices. Farmers with lower incomes, falling into the category of less than ₦50,000 (48.4% of the sample), may face financial constraints hindering the adoption of certain practices that require upfront investments (Sennuga, Fadiji and Thaddeus (2020). Conversely, those in the higher income brackets may have more financial flexibility to invest in sustainable technologies and practices. This underscores the need for targeted financial support mechanisms, such as subsidies or low-interest loans, to ensure that all farmers, irrespective of their income level, can actively participate in and benefit from climate-smart agriculture initiatives (Famine Early Warning Systems Network, 2018). Additionally, income diversification strategies, coupled with capacity-building programs, can contribute to overall farm resilience and sustainability in the face of climate change challenges.

Membership of Association: A substantial proportion of cassava farmers (66.7%) are actively engaged as members of agricultural associations. This finding aligns with that of Otekunrin and Sawicka (2019) who reported that social networks and community-based organizations play a pivotal role in influencing farmers' behaviors and decisions. Agricultural associations serve as platforms for knowledge exchange, peer learning, and collective decision-making, which are crucial aspects for the adoption of climate-smart agricultural practices (Hirwa et al., 2021). These associations provide a structured framework for disseminating information, organizing training programs, and accessing resources that can enhance farmers' capacity to adopt and implement sustainable practices. Leveraging the existing social capital within these associations can significantly contribute to the successful dissemination and adoption of climate-smart practices among cassava farmers in Delta State.

Number of Extension Contacts: About 34.9% of farmers report non-existent or infrequent contact (non or once a month), while 48.4% have contacts twice a month, and 9.5% have more frequent interactions. Extension services play a pivotal role in disseminating information about climate-smart agricultural practices (Sennuga, Fadiji and Thaddeus (2020). Farmers with limited contacts may face challenges accessing crucial knowledge, hindering their ability to adopt sustainable farming methods. It is imperative to consider these disparities in extension services when designing interventions, ensuring that information reaches all farmers, regardless of their frequency of contact.

Table 1: Socioeconomic Characteristics

Variable	Frequency	Percent	Mean
Gender			
Male	44	34.9	
Female	82	65.1	
Age			
Less than 20 years	13	10.3	
20 – 40 years	39	31.0	
41 – 61 years	41	32.5	45 years
Above 61 years	33	26.2	
Marital Status			
Single	35	27.8	
Married	54	42.9	
Divorced	24	19.0	
Widowed	13	10.3	
Level of Education			
No formal education	5	4.0	

Primary education	12	9.5	
Secondary education	80	63.5	
Tertiary	29	23.0	
Farm size (Ha)			
Less than 0.5	55	43.7	
0.5 – 1.0	32	25.4	0.9 hectares
1.01 – 1.5	15	11.9	
1.51 – 2.0	10	7.9	
Above 2.0	14	11.1	
Farming Experience (Years)			
1 – 5	25	19.8	
6 – 10	54	42.9	10 years
Above 10 years	47	37.3	
Farm monthly Income (₦)			
Less than 50,000	61	48.4	
50,000-99,999	19	15.1	₦73,016.26
100,000-149,999	26	20.6	
Above 149,999	20	15.9	
Membership of association			
Yes	84	66.7	
No	42	33.3	
Number of extension contacts (monthly)			
Non	44	34.9	
Once	61	48.4	
Twice	12	9.5	
More than twice	9	7.1	

3.2 Level of adoption of climate-smart agricultural practices among cassava farmers in Delta State

The result in Table 2 provides insights into the adoption levels of various climate-smart agricultural practices among cassava farmers in Delta State. The adoption of weather forecasting, with a mean score of 2.60, indicates a moderate level of integration. This aligns with the findings of Singh, Baxla, Singh and Singh (2019), who emphasized the importance of weather forecasting in managing climate risks for sustainable crop production. The moderate adoption suggests a recognition of the utility of weather information, although further efforts might be beneficial in promoting its widespread and effective use.

In contrast, the adoption of drought-resistant cassava varieties stands out with a higher mean score of 3.28. This aligns with the work of Cock and Connor (2021), emphasizing the significance of drought-tolerant cassava varieties in climate resilience. The elevated adoption level suggests that cassava farmers in Delta State are proactively embracing varieties that can withstand climate-induced stressors, showcasing an adaptive response to changing environmental conditions. This aligns with the climate-smart agriculture paradigm, emphasizing the importance of adaptive strategies to enhance agricultural sustainability (FAO, 2010).

The mean scores for soil conservation practices (2.98), water-efficient irrigation techniques (3.21), and crop diversification (3.15) collectively depict a moderate-to-high level of adoption. These practices are essential components of climate-smart agriculture, contributing to sustainable land use and resource optimization. This aligns with the findings of Rosenstock et al. (2014), who underscored the importance of these practices in building resilience and ensuring food security under changing climatic conditions. The moderate-to-high adoption levels suggest a positive trend toward sustainable farming practices among cassava farmers in Delta State.

Table 2: Level of adoption of climate-smart agricultural practices among cassava farmers in Delta State

Climate-smart agricultural practices	$\bar{x}$	Standard deviation
Weather forecasting	2.60	1.028
Drought-resistant cassava varieties	3.28	0.960
Soil conservation practices	2.98	0.899
Water-efficient irrigation techniques	3.21	0.990
Crop diversification	3.15	0.877

Where: $\bar{x} \geq 2.5$ = High adoption; $\bar{x} < 2.5$ = Low adoption

3.3 Socioeconomic factors influencing cassava farmers' decision to adopt climate-smart agricultural practices

Table 3 provides a detailed insight into the socioeconomic factors that significantly influence cassava farmers' decisions to adopt climate-smart agricultural practices, specifically focusing on drought-resistant cassava varieties, soil conservation practices, and water-efficient irrigation techniques.

Drought-Resistant Cassava Varieties: The adoption of drought-resistant cassava varieties among farmers in Delta State is significantly influenced by age and farming experience. The negative coefficient for age (B = -0.256, p = 0.006) indicates that as farmers' age increases, there is a decrease in the likelihood of adopting drought-resistant cassava varieties. This finding aligns with research by Dessart, Barreiro-Hurlé and Van Bavel (2019), suggesting that older farmers might be more conservative in their agricultural practices and less inclined to adopt newer, potentially riskier technologies. On the other hand, the positive coefficient for farming experience (B = 1.871, p = 0.002) highlights a strong association between greater farming experience and a higher likelihood of adopting drought-resistant cassava varieties. This finding resonates with studies emphasizing the positive correlation between experience and the adoption of innovative and climate-resilient agricultural practices (Ziro et al., 2023).
The results imply that interventions aimed at promoting the adoption of drought-resistant cassava varieties should consider age-related dynamics and develop targeted strategies to overcome potential resistance among older farmers. Additionally, initiatives should leverage the positive influence of farming experience by incorporating experienced farmers as knowledge-sharing resources within the community. Collaborative efforts involving agricultural extension services and farmer-to-farmer knowledge transfer programs may be effective in addressing age-related barriers and fostering the widespread adoption of drought-resistant cassava varieties in Delta State.

Soil Conservation Practices: Within the context of adopting soil conservation practices, the variable that significantly influences farmers' decisions is education (B = 0.234, p = 0.029). This finding underscores the crucial role of education in promoting sustainable agricultural practices. Farmers with higher levels of education are more likely to adopt soil conservation measures. This aligns with existing literature emphasizing the positive correlation between education and the adoption of environmentally friendly farming techniques (Challinor et al., 2018).
The positive coefficient for education implies that, as the level of education increases, the odds of adopting soil conservation practices also increase. Educated farmers may possess a better understanding of the long-term benefits of soil conservation, including improved soil fertility, reduced erosion, and enhanced crop yields. Moreover, educated farmers are likely to be more receptive to information disseminated through extension services, research findings, or other knowledge-sharing platforms (Ziro et al., 2023).
Educational interventions targeted at enhancing awareness and knowledge of soil conservation practices may be particularly effective in encouraging broader adoption. Policymakers and agricultural extension services can leverage these insights to design tailored programs and outreach strategies that specifically address the educational needs of farmers. Ultimately, investing in educational initiatives within farming communities can be a key driver for the widespread adoption of sustainable soil conservation practices in the study area.

Water-Efficient Irrigation Techniques:

The adoption of water-efficient irrigation techniques is a crucial aspect of climate-smart agricultural practices, as it directly addresses water scarcity concerns and contributes to sustainable water management. In the logistic regression analysis, two significant variables emerged as influencers of the adoption of water-efficient irrigation techniques among cassava farmers in Delta State.

The positive coefficient for annual farm income (B = 2.931, p = 0.025) suggests a strong association between farmers with higher incomes and the adoption of water-efficient irrigation techniques. This aligns with the findings of McCarthy et al. (2011), emphasizing that financial capacity plays a pivotal role in the adoption of climate-smart practices. Farmers with higher incomes are more likely to invest in advanced irrigation technologies, such as drip or sprinkler systems, which can optimize water use and enhance overall farm efficiency. Policymakers and agricultural extension services should consider financial support mechanisms or incentives for smallholder farmers to facilitate the adoption of these technologies, especially for those with limited resources.

The positive coefficient for extension contacts (B = 0.987, p = 0.039) indicates that farmers who have more frequent interactions with extension services are more likely to adopt water-efficient irrigation techniques. Extension services play a vital role in disseminating knowledge, providing technical assistance, and facilitating the adoption of innovative practices (Singh et al., 2019). These findings underscore the importance of strengthening extension services and promoting knowledge-sharing platforms to enhance farmers' awareness and understanding of water-efficient irrigation technologies. Collaborative efforts involving agricultural extension officers, researchers, and local communities can contribute to the successful dissemination and adoption of these climate-smart practices.

The results collectively highlight the nuanced relationship between socioeconomic factors and the adoption of water-efficient irrigation techniques. While income influences the financial feasibility of adoption, the role of extension services underscores the need for targeted interventions to enhance farmers' knowledge and bridge the information gap. Policymakers and stakeholders should consider holistic approaches that address both financial and informational barriers to promote the widespread adoption of water-efficient irrigation techniques among cassava farmers in Delta State.

The overall model summary indicates that the selected socioeconomic factors collectively explain a significant portion of the variability in farmers' adoption decisions (Chi-Square = 76.180, df = 27, p < 0.001). The pseudo R-squared values (Cox and Snell = 0.454, Nagelkerke = 0.534, McFadden = 0.319) suggest that the model is effective in explaining the variance in the adoption of climate-smart practices, reinforcing the importance of the identified socioeconomic factors.

Table 3: Socioeconomic factors influencing cassava farmers' decision to adopt climate-smart agricultural practices

Climate-smart agricultural practices	Variable	B	Std. Error	Wald	df	Sig.	Exp(B)
Drought-resistant cassava varieties	Intercept	0.324	3.909	0.007	1	0.934	
	Gender	-0.103	0.669	0.024	1	0.878	0.902
	Age	-0.256**	0.093	7.532	1	0.006	0.774
	Marital status	-2.066	1.538	1.805	1	0.179	0.127
	Education	-0.132	0.161	0.673	1	0.412	0.876
	Farming experience	1.871***	0.590	10.061	1	0.002	6.493
	Farm size	-0.150	0.206	0.530	1	0.467	0.861
	Annual farm income	0.135	0.336	0.162	1	0.688	1.145

	Membership of Asso.	0.000	0.000	0.297	1	0.586	1.000
	Extension contacts	2.855**	1.395	4.190	1	0.041	17.371
Soil conservation practices	Intercept	-2.321	2.871	0.653	1	0.419	
	Gender	0.537	0.918	0.342	1	0.559	1.711
	Age	-0.033	0.051	0.435	1	0.510	0.967
	Marital status	0.357	0.951	0.141	1	0.707	1.429
	Education	0.234**	0.107	4.756	1	0.029	1.264
	Farming experience	0.056	0.259	0.046	1	0.830	1.057
	Farm size	0.010	0.132	0.005	1	0.942	1.010
	Annual farm income	0.134	0.244	0.302	1	0.583	1.143
	Membership of Asso.	0.000	0.000	0.799	1	0.371	1.000
	Extension contacts	0.452	0.472	0.916	1	0.338	1.571
Water-efficient irrigation techniques	Intercept	-3.142	3.626	0.750	1	0.386	
	Gender	0.279	0.272	1.051	1	0.305	1.322
	Age	0.098	0.064	2.345	1	0.126	1.103
	Marital status	0.580	1.206	0.231	1	0.631	1.786
	Education	-0.141	0.130	1.181	1	0.277	0.868
	Farming experience	-0.280	0.295	0.902	1	0.342	0.756
	Farm size	0.047	0.163	0.084	1	0.772	1.048
	Annual farm income	2.931**	1.310	5.008	1	0.025	0.053
	Membership of Asso.	0.000	0.000	0.653	1	0.419	1.000
	Extension contacts	0.987**	0.523	3.559	1	0.039	2.684
Model summary							
-2 Log Likelihood	**Chi-Square**	**df**	**Sig.**	**Cox and Snell**	**Nagelkerke**	**McFadden**	
162.636	76.180	27	0.000	0.454	0.534	0.319	

Where: ** and *** are significant at 5% and 1% probability levels respectively

3.4 Constraints faced by cassava farmers on the use climate-smart agricultural practices in the study area

Table 4 presents the perceived constraints faced by cassava farmers in Delta State regarding the adoption of climate-smart agricultural practices. Cassava farmers in Delta State identify limited access to information and extension services as a highly challenging constraint, evident from the high mean score of 3.73. This aligns with studies by Takahashi, Muraoka and Otsuka (2020), emphasizing the pivotal role of extension services in disseminating information on climate-smart practices. Addressing this constraint is imperative for enhancing farmers' knowledge and facilitating the effective adoption of sustainable farming methods. Additionally, financial constraints emerge as a substantial barrier ($\bar{x}$ = 3.56), resonating with McCarthy et al. (2011), who highlighted the financial implications associated with climate-smart practices. Policies and interventions providing financial support, such as subsidies or accessible credit, are essential to alleviate this constraint and promote widespread adoption.

Constraints with moderate mean scores include lack of infrastructure ($\bar{x}$ = 3.21) and pest and disease pressure ($\bar{x}$ = 3.25). The perception of inadequate infrastructure aligns with McCarthy, Lipper and Zilberman (2018), emphasizing the role of infrastructure in facilitating the adoption of climate-smart practices. Strengthening rural infrastructure is crucial for overcoming logistical challenges associated with implementing sustainable farming methods. The concern regarding pest and disease pressure is in line with the vulnerability of cassava to pests and diseases, as highlighted by Savary et al. (2012). Integrated pest management strategies and the development of disease-resistant varieties are essential components in mitigating this constraint and ensuring sustainable cassava production.

Constraints with relatively lower mean scores include climate variability and unpredictability ($\bar{x} = 2.93$), lack of access to credit ($\bar{x} = 2.73$), inadequate research and development ($\bar{x} = 2.89$), and limited social capital ($\bar{x} = 2.91$). The moderate agreement regarding climate variability aligns with research by Clay and Zimmerer (2020), emphasizing the need for adaptive strategies in the face of changing climate patterns. Addressing issues related to credit access, research and development, and social capital involves collaborative efforts between farmers, research institutions, and policymakers to create an enabling environment for the adoption of climate-smart practices. The comprehensive understanding of these constraints is essential for designing targeted interventions and policies that address the specific challenges faced by cassava farmers in Delta State, ultimately fostering the widespread adoption of climate-smart agricultural practices.

Table 4: Constraints faced by cassava farmers on the use climate-smart agricultural practices in the study area

Constraints	Mean	Standard deviation
Limited Access to Information and Extension Services	3.73	0.814
Financial Constraints	3.56	0.711
Lack of Infrastructure	3.21	0.711
Land Tenure Issues	3.05	0.747
Pest and Disease Pressure	3.25	0.838
Climate Variability and Unpredictability	2.93	0.761
Lack of Access to Credit	2.73	0.804
Inadequate Research and Development	2.89	0.802
Limited Social Capital	2.91	0.693

Where: $\bar{x} \geq 2.5$ = Agreed; $\bar{x} < 2.5$ = Disagreed

CONCLUSION

This study analysed the adoption of climate-smart agricultural practices among smallholder cassava farmers in Delta State, Nigeria. The findings indicate moderate adoption levels for weather forecasting, drought-resistant varieties, soil conservation, water-efficient irrigation, and crop diversification. However, there remains substantial room for improvement to accelerate the transition towards climate-resilient, sustainable production systems. The study identified key socioeconomic factors influencing farmers' decisions to adopt specific climate-smart practices. Age and farming experience were significant for adopting drought-tolerant varieties; education level for soil conservation practices; and annual income and extension contacts for water-efficient irrigation. These highlight the need for targeted strategies catering to the unique barriers and motivations across different demographic groups.

Additionally, the study revealed the foremost constraints hindering climate-smart agriculture adoption to be limited access to information and extension services, financial limitations, inadequate infrastructure, and pest/disease susceptibility. A multidimensional approach addressing these economic, institutional, technical and social challenges is imperative. Overall, while initial progress is evident, substantial efforts remain vital across policy, research and grassroots extension to promote the widespread adoption of climate-resilient practices. Embracing context-specific solutions and participatory engagement with farmers will be key to successful implementation. The future productivity and resilience of Nigeria's vital cassava sector depends on the sector's agile adaptation in the face of climate change. Based on the study's findings, the following recommendations are proposed for relevant stakeholders:

i. Agricultural extension agencies should enhance regular farmer interactions through mobile platforms and community hubs to bridge information gaps regarding climate risks and adaptation options.
ii. Local Government and NGOs should establish affordable pilot programs for farmers to test climate-smart equipment like drip irrigation, with accompanying training.
iii. Microfinance groups and social enterprises should facilitate access to credit for smallholders to alleviate financial limitations in adopting new practices.
iv. Agricultural research institutes should strengthen participatory research with farmers to accelerate innovation tailored to local conditions.
v. Policymakers should develop educational initiatives, subsidies and rural infrastructure investments to remove barriers and create an enabling environment.
vi. Farmer associations should leverage peer learning to introduce climate-smart techniques through local champion farmers as role models.
vii. Development partners should support vulnerability assessments and progress monitoring to inform evidence-based planning and interventions.

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