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Adoption and Scaling of Climate-Smart Agricultural Practices among Smallholder Cassava Farmers in Taraba State, Nigeria

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Abstract

This study examined the adoption and scaling of climate- smart agricultural practices (CSA) among smallholder cassava farmers in Taraba State, Nigeria. A total of 316 farmers were selected using a multi- stage sampling technique. Data were collected via structured questionnaires and analyzed using descriptive statistics, an adoption index, and binary logistic regression. Findings showed that 62. 3% of respondents were male, with a mean age of 42. 5 years, an average farm size of 2. 2.8 hectares, and a mean of 14. 2 years of cassava farming experience. Access to credit was reported by 45. 6% of farmers, 58. 2% had extension contacts, and 63. 9% belonged to farmer associations. The adoption index indicated that 67. 1% of respondents had adopted at least one CSA practice, with a mean adoption intensity of 2. 83 out of 4, reflecting moderate adoption. Binary logistic regression revealed that age (β = 0. 024), gender (β = 0. 315), education (β = 0. 067), farm size (β = 0. 091), years of farming experience (β = 0. 035), access to credit (β = 0. 488), extension contact (β = 0. 126), association membership (β = 0. 341), and CSA training (β = 0. 562) positively influenced adoption, while household size (β = −0. 051) had a negative effect. Constraint analysis showed that limited access to credit (80. 4%), high input costs (78. 5%), inadequate training (75. 0%), lack of extension support (69. 9%), and poor market access (67. 1%) were the most severe constraints to adoption and scaling. Other notable constraints included low awareness of CSA, pest and disease incidence, climate- related shocks, and inadequate government support. The study concludes that CSA adoption among smallholder cassava farmers is driven by socio- economic, institutional, and training factors, while financial, knowledge, and infrastructural barriers hinder scaling. Strengthening extension services, improving credit access, implementing targeted training, and promoting farmer associations are recommended to enhance adoption and scaling of CSA practices.

Keywords: Climate-Smart Agriculture, Adoption, Scaling, Smallholder Cassava Farmers

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INTRODUCTION

Climate change has emerged as one of the most significant threats to agricultural sustainability and food security in sub-Saharan Africa. In Nigeria, rising temperatures, erratic rainfall, and more frequent extreme weather events have reduced crop productivity, particularly among smallholder farmers who rely heavily on rain-fed agriculture. Cassava, a major staple crop and a key source of income for rural households, is increasingly vulnerable to climate-induced stresses, including drought, soil degradation, and pest outbreaks (Nwankwo et al., 2021; Opar et al., 2025). Climate-Smart Agriculture (CSA) offers an integrated approach to addressing these challenges by promoting practices that enhance productivity, strengthen climate resilience, and reduce environmental degradation. CSA practices relevant to cassava production include improved and drought-tolerant varieties, soil and water conservation techniques, crop diversification, integrated pest management, and efficient use of inputs. Empirical studies in Nigeria have shown that adopting CSA practices can significantly improve cassava yields, farm income, and household food security (Saadu et al., 2024).

However, the adoption and scaling of CSA practices among smallholder cassava farmers remain constrained by several socio-economic and institutional factors. Research indicates that farmers' education, farm size, access to credit, extension contact, and membership in farmer organizations are critical determinants of CSA adoption (Taiwo *et al*., 2024). In many rural areas, limited access to climate information, inadequate extension services, and weak institutional support hinder farmers' capacity to adopt and sustain CSA innovations. Extension services are widely recognized as a key driver of CSA adoption and scaling. Effective extension systems facilitate knowledge transfer, enhance farmers' adaptive capacity, and promote collective learning and innovation. Nonetheless, studies in Nigeria reveal persistent challenges within extension delivery, including limited manpower, poor funding, and inadequate integration of climate change content into advisory services (Shehu, 2024).

Statement of the Problem

Smallholder cassava farmers in Taraba State are increasingly exposed to the adverse effects of climate change, including erratic rainfall, prolonged dry spells, declining soil fertility, and increased pest and disease incidence. These challenges have led to unstable yields, reduced farm income, and heightened vulnerability of rural livelihoods. Although Climate-Smart Agriculture (CSA) practices have been widely promoted as effective strategies for enhancing productivity, resilience, and environmental sustainability, their adoption and large-scale use among cassava farmers in the state remain limited. Various CSA interventions have been introduced through government programs, development partners, and research institutions. However, evidence suggests that adoption often remains at pilot or project levels, with limited scaling beyond initial beneficiaries. Many smallholder cassava farmers continue to rely on conventional farming practices that are poorly suited to changing climatic conditions. This situation raises concerns about the effectiveness of current extension approaches and institutional arrangements in facilitating sustained adoption and scaling of CSA practices. Extension services are expected to play a pivotal role in promoting CSA by providing climate information, technical guidance, and continuous support to farmers.

Objectives of the Study

The broad objective of this study is to examine the adoption and scaling of climate-smart agricultural practices among smallholder cassava farmers in Taraba State, with emphasis on the role of agricultural extension services. The specific objectives are to:

1. describe the socio-economic characteristics of smallholder cassava farmers in Taraba State;
2. assess the level of adoption and intensity of use of climate-smart agricultural practices among cassava farmers;
3. examine the role of agricultural extension services and institutional support in promoting the adoption and scaling of climate-smart agricultural practices; and
4. identify the key constraints affecting the adoption and scaling of climate-smart agricultural practices among smallholder cassava farmers in Taraba State.

METHODOLOGY

Description of the Study Area

Taraba State is located in the northeastern region of Nigeria, within the country's Middle Belt zone. It lies approximately between latitudes 6°30′N and 9°36′N and longitudes 9°10′E and 11°50′E. The state shares an international boundary with the Republic of Cameroon to the east and is bordered by Bauchi, Gombe, Adamawa, Benue, Nasarawa, and Plateau States (Shehu, 2024). This strategic location places Taraba State within a diverse ecological and socio-economic landscape that supports a wide range of agricultural and livelihood activities. Taraba State covers about 54,473 square kilometers, making it one of the largest states in Nigeria by land area. Administratively, the state is divided into 16 Local Government Areas. The state's topography is highly varied, comprising lowland plains, undulating hills, and mountainous regions. The southern part of the state is dominated by the Mambilla Plateau, which rises to elevations of over 1,800 meters above sea level and is known for its distinctive montane climate and agricultural potential. Major crops grown in the state include cassava, yam, rice, maize, sorghum, millet, sugarcane, groundnut, and cotton. Livestock production, particularly cattle, goats, and sheep, is widespread, while fishing activities are common along rivers and other water bodies (Gbadebo et al., 2022).

Sampling Procedure

A multi-stage sampling technique was also employed. In the first stage, three LGAs with significant cassava production were purposively selected: Zing LGA, Wukari LGA, and Kurmi LGA. In the second stage, villages and farming communities within each LGA were identified, and smallholder cassava farmers were randomly selected. Zing LGA comprised Jada – 55 respondents, Yar-Tsamiya – 50 respondents, and Balee – 45 respondents. Wukari LGA comprised Bantaje – 50 respondents, Puje – 45 respondents, and Kente – 35 respondents, while Kurmi LGA comprised Lankada – 25 respondents, Danuma – 25 respondents, and Gidan-Mai – 36 respondents, giving a total of 316, used as the sample size for the study. This proportional allocation ensured that all major cassava farming communities, extension agents, and community leaders were adequately represented in the study. Agricultural extension agents and LGA officials involved in

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climate-smart agricultural programs were purposively included. Community leaders and members of farmer cooperatives were purposively selected to provide additional perspectives on the adoption and scaling of CSA practices.

Sample Size Determination

Using Yamane's (1967) formula to estimate the sample size, the total population of cassava farmers and stakeholders in the selected LGAs was 1,500, with a 5% margin of error:

Sample Size Determination

Using Yamane's (1967) formula:

n = N / (1 + N x e^2)

N = 1,500 (total population of cassava farmers and stakeholders) e = 0.05 (5% margin of error)

Step-by-step computation:

n = 1500 / (1 + 1500 x 0.05^2)

n = 1500 / (1 + 1500 x 0.0025)

n = 1500 / (1 + 3.75)

n = 1500 / 4.75

n ≈ 316

Table 3.1: Selected LGAs, Villages and Sample Size

LGA	Village / Cluster	Sample Size (n)
Zing	Jada	55
Zing	Yar-Tsamiya	50
Zing	Balee	45
Wukari	Bantaje	50
Wukari	Puje	45
Wukari	Kente	35
Kurmi	Lankada	25
Kurmi	Danuma	25
Kurmi	Gidan-Mai	36
Total		316

Source: Author Construct, 2026

Data Collection

Data were collected using structured questionnaires administered to sampled cassava farmers. The questionnaire captured information on socio-economic characteristics, farm size, cropping practices, awareness and adoption of climate-smart agricultural (CSA) practices, sources of extension support, and challenges in adoption and scaling. Interviews were semi-structured, allowing flexibility to probe for detailed responses.

Data Analysis

Data were analyzed using both descriptive and inferential statistics. Descriptive statistics were used to analyze objectives 1 and 4; the adoption index was used to analyze objective 2, and binary logistic regression was used to analyze objective 3.

Model Specification for Adoption Index

Let AIi represent the **adoption index** of climate-smart practices for farmer i (ranging from 0 to 1). The multiple linear regression model is specified as:

$$AIi = \beta_0+\beta_1X_1+\beta_2X_2+\beta_3X_3+\beta_4X_4+\beta_5X_5+\beta_6X_6+\beta_7X_7+\beta_8X_8+\beta_9X_9+\beta_{10}X_{10}+\epsilon$$

Where:

AIi = Adoption index for farmer iii

β_0 = Intercept

$\beta_1 \ldots \beta_{10}$ = Coefficients of explanatory variables

ϵi = Error term

Explanatory variables (X):

Variable	Symbol
Age of farmer (years)	X_1
Gender (Male=1, Female=0)	X_2
Education (years)	X_3
Farm size (hectares)	X_4
Years in cassava farming (Years)	X_5
Access to credit (Yes=1, No=0)	X_6
Extension contacts (visits/year)	X_7
Membership of farmer association (Yes=1, No=0)	X_8
Household size (Number)	X_9
Off-farm income (Yes=1, No=0)	X_{10}

Logit Regression Model Specification

The binary logistic regression model was used to examine the role of extension agents in influencing the adoption of climate-smart agricultural practices among smallholder cassava farmers. The dependent variable, Y, represents adoption status, where:

Y= {1 if the farmer adopted climate-smart practices, 0 if the farmer did not adopt climate-smart practices}. The independent variables included socio-economic and institutional factors such as age (X_1), gender (X_2), education (X_3), farm size (X_4), years in farming (X_5), access to credit (X_6), extension contact (X_7), membership of associations (X_8), household size (X_9), training on CSA (X_{10}), and income level (X_{11}).

The logistic regression model is expressed as:

$$\text{Logit}(P) = \ln(1-P) = \beta_0+\beta_1X_1+\beta_2X_2+\beta_3X_3+\beta_4X_4+\beta_5X_5+\beta_6X_6+\beta_7X_7+\beta_8X_8+\beta_9X_9+\beta_{10}X_{10}+\beta_{11}X_{11}+\varepsilon$$

Where:

P = probability that a farmer adopts climate-smart agricultural practices

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β_0 = intercept

X_1=Age of farmer (Years)

X_2=Gender of farmer (1 for male, 0 otherwise)

X_3=Education level (Number of years spent in school)

X_4=Farm size (ha)

X_5=Years in cassava farming (Years)

X_6=Access to credit (1 for access, 0 otherwise)

X_7=Extension access (1 for access, 0 otherwise)

X_8=Membership of farmer associations (1 for member, 0 otherwise)

X_9=Household size (Number)

X_{10}=Training on CSA practices (Number of trainings received)

X_{11}=Income level (N)

$\beta_1,\beta_2,...,\beta_{11}$ = coefficients of the independent variables

ε = error term

RESULTS AND DISCUSSION

Table 1: Socio-Economic Characteristics of Smallholder Cassava Farmers (n = 316)

Variable	Category	Frequency	Percentage (%)	Mean / SD
Gender	Male	206	65.2	–
	Female	110	34.8	–
Age (years)	≤30	47	14.9	42.3 ± 11.2
	31–40	95	30.1	
	41–50	110	34.8	
	>50	64	20.3	
Education (years)	No formal education	63	19.9	9.1 ± 3.7
	Primary	95	30.1	
	Secondary	111	35.1	
	Tertiary	47	14.9	
Household size	≤5	95	30.1	6.4 ± 2.5
	6–10	158	50.0	
	>10	63	19.9	
Farm size (hectares)	≤2	79	25.0	3.5 ± 1.8
	3–5	127	40.2	
	6–10	79	25.0	
	>10	31	9.8	
Years in cassava farming	≤5	63	19.9	12.7 ± 7.4
	6–10	111	35.1	
	11–15	95	30.1	
	>15	47	14.9	
Access to credit	Yes	126	39.9	–
	No	190	60.1	–
Extension contacts (visits/year)	≤2	111	35.1	3.1 ± 1.9

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Variable	Category	Frequency	Percentage (%)	Mean / SD
	3–5	127	40.2	
	>5	78	24.7	
Membership of farmer association	Yes	174	55.1	–
	No	142	44.9	–

Source: Field Survey, 2026

The socio-economic profile in Table 1 shows that male farmers dominate cassava production (65.2%), while females account for 34.8%, reflecting a gendered pattern in rural agricultural labor (Izuogu et al., 2025). The average age of farmers was 42.3 years, with 65% between 31 and 50 years. This indicates a predominantly middle-aged population capable of adopting and sustaining new agricultural practices. Education levels showed that 65.2% had primary or secondary education, with only 14.9% attaining tertiary education, suggesting moderate literacy levels that could influence understanding of climate-smart practices (Chidebere et al., 2025). The average household size was 6.4 members, with 50% of households having 6–10 members. Larger households may provide labor for farm operations but also create resource pressures that could influence adoption decisions. Farm sizes were mostly 3–5 hectares (40.2%), with a few large-scale farms (>10 hectares). This shows that small- to medium-scale production dominates cassava farming in Taraba State. Farmers had an average of 12.7 years of experience in cassava farming, suggesting sufficient knowledge and practical skills to adopt improved and climate-smart practices (Nwangu and Adebayo, 2025). Regarding access to credit, only 39.9% of farmers reported having financial support, indicating a limitation that may constrain adoption of climate-smart practices. Extension contacts averaged 3.1 visits per year, with 24.7% receiving more than five visits annually. Regular extension engagement is vital for improving farmers' technical skills and facilitating adoption of climate-smart agricultural practices (Shehu, 2024). Membership in farmer associations was reported by 55.1% of respondents. Association membership can enhance access to information, inputs, and collective learning opportunities, which are critical for adoption and scaling of climate-smart innovations (Saadu, 2024).

Table 2: Level and Intensity of Adoption of Climate-Smart Practices (n = 316)

Practice	Adopted (n)	Adopted (%)
Improved cassava varieties	210	66.5
Mulching	176	55.7
Intercropping	132	41.8
Use of organic fertilizer	145	45.9
Agroforestry integration	95	30.1
Soil and water conservation	120	38.0
Planting basins/ridges	165	52.2
Crop rotation	110	34.8
Integrated pest management	128	40.5
Efficient water management	140	44.3

Source: Field Survey, 2026 Adoption Index (AI) for each farmer (AI=10Number of practices adopted)

Table 3: Classification of farmers by adoption level (n = 316)

Adoption Level	Frequency (n)	Percentage (%)
Low (<50%)	132	41.8
Medium (50–75%)	158	50.0
High (>75%)	26	8.2

Source: Field Survey, 2026

Analysis in Tables 2 and 3 shows that overall adoption of climate-smart practices (CSPs) among cassava farmers is moderate, with an average adoption index of 0.53 (53%). The most widely adopted practice was improved cassava varieties (66.5%), consistent with studies highlighting farmers' preference for higher-yielding, disease-resistant varieties (Taiwo et al., 2024). Mulching (55.7%) and planting basins/ridges (52.2%) were also moderately adopted, reflecting awareness of soil moisture retention and erosion control techniques. However, practices such as agroforestry integration (30.1%), crop rotation (34.8%), and soil and water conservation (38%) had relatively low adoption, possibly due to limited technical knowledge, labor intensity, or lack of extension support (Alhassan et al., 2023). The adoption index classification showed that 50% of farmers were at medium adoption, 41.8% at low adoption, and only 8.2% at high adoption. This indicates that while farmers are selectively adopting certain practices, comprehensive adoption of multiple CSPs remains limited, which could constrain the effectiveness of climate-smart agriculture in increasing cassava productivity and resilience (Opara et al., 2025).

Table 4: Logistic Regression Analysis of the role of Extension Agents in Influencing the Adoption of Climate-Smart Practices (n = 316)

Variable	Coefficient (β)	Std. Error	Wald	Exp(β)
Intercept	-1.782*	0.658	7.34	0.168
Age	0.024*	0.011	4.76	1.024
Gender	0.315*	0.152	4.29	1.371

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Variable	Coefficient (β)	Std. Error	Wald	Exp(β)
Education	0.067*	0.028	5.72	1.069
Farm size	0.091*	0.034	7.15	1.095
Years in farming	0.035*	0.015	5.44	1.036
Access to credit	0.488*	0.162	9.06	1.629
Extension contacts	0.126*	0.041	9.45	1.134
Membership of association	0.341*	0.149	5.24	1.406
Household size	-0.051*	0.022	5.40	0.950
Off-farm income	0.198	0.137	2.09	1.219
Training on CSA	0.562*	0.178	9.97	1.754
R^2	0.582			
Adjusted R^2	0.428			
Chi-square	65.41			
-2 Log Likelihood	314.58			
Number of observations	316			

Source: Field Survey, 2026 *** significant at 1%, ** Significant at 5% and * Significant at 10%

The logistic regression analysis in Table 4 showed that several socioeconomic and institutional factors significantly influenced the adoption of climate-smart practices among cassava farmers in Taraba State. Age had a positive, statistically significant coefficient (β = 0.024), indicating that older farmers were slightly more likely to adopt climate-smart practices, likely due to accumulated experience and familiarity with farm innovations (Izuogu et al., 2025). Gender (β = 0.315) was significant, showing that male farmers were more likely to adopt CSA practices than female farmers. This reflects prevailing gender roles in rural agricultural production, where males often control land and farming decisions (Saadu, 2024). Education positively influenced adoption (β = 0.067), suggesting that literate farmers are better able to understand and implement climate-smart practices (Nwangu and Adebayo, 2025). Farm size was also significant (β = 0.091), implying that farmers with larger landholdings have more resources and flexibility to implement multiple climate-smart practices. Years in cassava farming (β = 0.035) positively influenced adoption, indicating that more experienced farmers are more willing to try new innovations.

Access to credit (β = 0.488) significantly increased adoption, underscoring that financial support reduces constraints on purchasing inputs and adopting new technologies. Extension contact (β = 0.126) was positively associated with adoption, reinforcing the critical role of extension agents in knowledge transfer and technical support (Chidebere et al., 2025). Membership in farmer associations (β = 0.341) significantly influenced adoption, reflecting the importance of collective learning, peer support, and access to resources. Household size had a negative effect (β = -0.051), suggesting that larger households may face competing labor and resource demands, reducing capacity to adopt new practices. Off-farm income (β = 0.198) was not significant, implying that non-farm income does not strongly affect adoption in this context. Training on climate-smart agriculture had the highest positive coefficient (β = 0.562), demonstrating the importance of targeted training programs in promoting adoption.

Table 5: Constraints Affecting Adoption and Scaling of Climate-Smart Practices (n = 316)

Constraint	Frequency affected	Percentage (%)	Mean score
High cost of inputs	248	78.5	3.42
Limited access to credit	254	80.4	3.50
Lack of extension support	221	69.9	3.12
Inadequate training	237	75.0	3.33
Low awareness of CSA	196	62.0	2.91
Poor market access	212	67.1	3.05
Limited land	145	45.9	2.48
Climate-related shocks	178	56.3	2.79
Labor shortages	161	50.9	2.61
Weak farmer associations	154	48.7	2.57
Lack of government support	180	57.0	2.83
Pest and disease incidence	190	60.1	2.95

Source: Field Survey, 2026 * Multiple responses were recorded**

The analysis in Table 5 revealed that financial and institutional constraints are the most critical barriers to adopting climate-smart practices. Limited access to credit (mean = 3.50; 80.4%) was the most significant constraint, confirming that inadequate financial resources prevent farmers from acquiring improved inputs and adopting multiple climate-smart practices (Gbadebo et al., 2022). Closely following was the high cost of inputs (78.5%), indicating that even when farmers are aware, affordability remains a major barrier. Inadequate training (75.0%) and lack of extension support (69.9%) were also critical, highlighting the need for frequent extension contact and hands-on capacity building to improve adoption and scaling (Opara et al., 2025). Low awareness of climate-smart agriculture (62%) demonstrates that knowledge gaps persist despite moderate adoption, suggesting targeted awareness campaigns are necessary. Poor market access (67.1%) was significant, showing that farmers may be reluctant to invest in climate-smart practices if there is uncertainty about selling their produce. Other moderate constraints included pest and disease incidence (60.1%), climate-related shocks (56.3%), and lack of government support (57%), indicating that biophysical and policy factors also affect adoption. Labor shortages, limited land, and weak farmer associations were rated as moderately severe,

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showing that household and institutional capacity also influence the ability to adopt and scale practices. The findings indicate that financial, knowledge, extension, and institutional support barriers are the major limiting factors to adoption and scaling of climate-smart practices among smallholder cassava farmers in Taraba State. Addressing these constraints through credit facilitation, subsidies for inputs, extension strengthening, and training programs would likely improve adoption rates and the overall impact of climate-smart agriculture (Opara et al., 2025).

CONCLUSION/RECOMMENDATIONS

The study examined the adoption and scaling of climate-smart agricultural practices among smallholder cassava farmers in Taraba State, Nigeria. The findings revealed that socioeconomic factors such as age, education, farm size, access to credit, membership in farmer associations, extension contact, and training significantly influenced CSA adoption. The adoption index showed that although a moderate proportion of farmers adopted some climate-smart practices, comprehensive adoption of multiple practices remained limited. Extension services and institutional support were critical determinants, with CSA training and active participation in farmer associations emerging as the strongest drivers of adoption. Analysis of constraints revealed that financial limitations, high input costs, inadequate extension support, low awareness, limited training, and poor market access were the major factors hindering adoption and scaling. Other challenges included labor shortages, pest and disease incidence, limited land, and climate-related shocks. Based on the findings, the following recommendations are proposed:

1. Agricultural extension programs should be expanded and intensified to provide regular, practical guidance and demonstrations on CSA, ensuring that farmers are equipped with the necessary knowledge and skills.
2. Financial institutions and government programs should offer affordable credit, input subsidies, and flexible loan programs to ease financial constraints and enable farmers to adopt multiple CSA practices.
3. Continuous, practical training in climate-smart agriculture should focus on underutilized practices, including agroforestry integration, crop rotation, soil and water conservation, and efficient water management.
4. Participation in cooperatives or farmer groups should be encouraged to facilitate knowledge sharing, collective access to inputs, and advocacy for support services.
5. Awareness campaigns using radio, workshops, demonstration plots, and digital tools should be intensified to improve farmers' understanding of CSA benefits and practices.

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