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Assessment of climate-smart agricultural practices of plantain farmers in Anambra State, Nigeria

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Abstract. *Emmanuel OE, Nnenna OM, Nkiruka B-CG, Anulika UO, Thankgod EK, Angela ON, Nwuguru NR, Ekunyi UN, Ighokpozi OE, Ajah OE, Chinenyenwa T-AA, Olivia OC, Marylilian OO, AGU OP, Rhoda IT, Ojochenemi I, Chukwuka CC. 2025. Assessment of climate-smart agricultural practices of plantain farmers in Anambra State, Nigeria. Asian J Agric 9: 140-148.* The study examined the climate-smart agricultural practices of plantain farmers in Anambra State, Nigeria. The study used a multistage sampling technique to select 76 plantain farmers. A structured questionnaire was used for primary data collection, and mean, descriptive statistics, multivariate probit regression, and factor analysis models were employed in the analysis. The result shows that the plantain farmers were middle-aged (46 years), females (59.2%), married (53.9%), with a household size of 7 persons and farming experience of 18 years. The result further shows that 75% of the plantain farmers were aware of climate change. Climate-smart agricultural (CSA) practices adopted include mixed farming (80.3%), movement to different sites (68.4%), planting of early maturing variety (86.8%), crop rotation (88.2%), and application of farm yard manure (71.1%). Age, gender, level of education, household size, farm size, farming experience, extension contacts, credit use, and victim of climate events statistically influenced the adoption of CSA practices. Problems of capital, soil fertility, lack of technical know-how, poor extension access, lack of timely information on weather conditions, instability in the planting calendar, high cost of inputs, and limited lands constrained plantain production and adoption of CSA practices. Efforts should be made to provide farmers with training and workshops on climate-smart agricultural practices; this will enhance their knowledge to make informed decisions in adopting CSA practices in mitigating climate change.

Keywords: Agricultural practices, assessment, climate-smart, plantain farmers

INTRODUCTION

Plantain (*Musa paradisiaca* L.) has occupied a strategic position in agricultural production across the continents over the years (Adi 2024). It represents the world's second-largest fruit crop, with Cameroon being the world's leading country in plantain production with 4.3 million tons, followed by Ghana with 4 million tons, Uganda with 3.7 million tons, Colombia with 3.5 million tons and Nigeria with 3.1 million tons (FAOSTAT 2023). The crop ranks as the fourth most important starchy food commodity after rice, wheat, and maize (FAOSTAT 2023). About 70 million people in Africa depend on plantain for more than 25 and 10% of their carbohydrate and calorie intake, respectively (FAO 2022). The plantain farming sector in Nigeria is small. However, its production contributes to the national gross domestic product and remains significant in terms of food production, food value chain, and improvement of rural livelihoods. According to Ayeh et al. (2023), it is an important source of revenue for many smallholder farmers. Thus, sustaining livelihoods in sub-Saharan African countries, including Nigeria, is important. Despite these gains from plantain production, its cultivation relied primarily on climate continuously changing over time (Ojo et al. 2024). The agricultural sector is expected to produce food for the global population that will reach 9.1 billion people in 2050 and over 10 billion by the end of the century (WorldBank 2023).

The sector's reliance on climate is faced with several challenges that impede food production and frustrate the farmers efforts and commitment to agricultural activities. Climate change has led to significant changes and adverse impacts on the economic livelihoods of local plantain household farmers (Fofana et al. 2024). These impacts are envisaged to worsen over the coming years due to livelihood pressures and frequent occurrences of natural hazards such as extreme temperature, drought, and flood (Yahaya 2019). Extreme climate events, such as high-temperature stress, drought, and flooding, severely reduce plantain production. Plantain crops require much water to germinate, develop, and grow evenly. However, with consistent shortfalls in rainfall and its abnormal variations, plantain production suffers distorted growth and development, leading to decreased yield, loss in income, and economic market value (Mohammadi et al. 2023). Climate changes determine the pattern of vegetation, types, and yields of crops and animals. The length of cropping seasons causes a considerable yield loss in plantain crops, thereby adversely affecting smallholder plantain farmers (modification of plantain production and food systems, introducing uncertainty and vulnerability risks) and food security (Mall et al. 2017; FAO 2023; Fofana et al. 2024).

Considering these negative consequences of climate change, various international institutions are working together with the World Bank Group and the Food and Agricultural Organization (FAO) to devise agricultural systems that will enhance and boost food production at all levels. According to Bai et al. (2024), agricultural systems need to be transformed to increase the productive capacity and stability of smallholder farmers in the wake of climate change. In this context, a global shift to Climate-Smart Agriculture (CSA) has been applauded by various institutions, stakeholders, researchers, policymakers, and agro-investors and across private, public, and civil society sectors (Ma and Rahut 2024). According to FAO (2024), the practice of CSA sustainably increases productivity, reduces climate change risks and vulnerability, enhance adaptation, and reduces emissions that cause climate change (mitigation), while protecting the environment against degradation and denudation.

Studies (Keil et al. 2021; Waaswa et al. 2022; Mohammadi et al. 2023; Omotoso and Omotayo 2024; Ojo et al. 2024; Cuni-Sanchez et al. 2025) have x-rayed the impacts of climate change on important food crops such as cassava, rice, yam, millets, cowpea, maize, vegetables, etc., which is commendable but however, studies on climate change and plantain cultivation are quite scanty and poorly documented, hence the rationale for the study. The study assessed the coping strategies of plantain farmers in the face of climate change in Anambra State, Nigeria.

MATERIALS AND METHODS

Study area

The study was conducted in Anambra State, Nigeria (Figure 1). It is located between longitude 6°36'E to 7°21'E and latitude 5°38'N to 6°47'N with a land mass of 4415.54 square kilometers. The state has fertile land holdings rich for agricultural production. Farming and trading are the most predominant occupation of the people, and majority of the farmers are smallholders. The area belongs to the densely populated rainforest zone of the country with two vegetation seasons, which are notably the rainy and dry seasons. The climate varies with temperatures around 25 to 27°C and rainfall around 1200 mm. The soil types include loamy, sandy, humus, and clay, while agricultural activities are carried out on the dark loamy and humus soil. The major crops produced are plantain, yam, cassava, rice, maize, cocoyam, cowpea, tomatoes, and vegetables, while the livestock produced in the state include poultry, sheep, and goats.

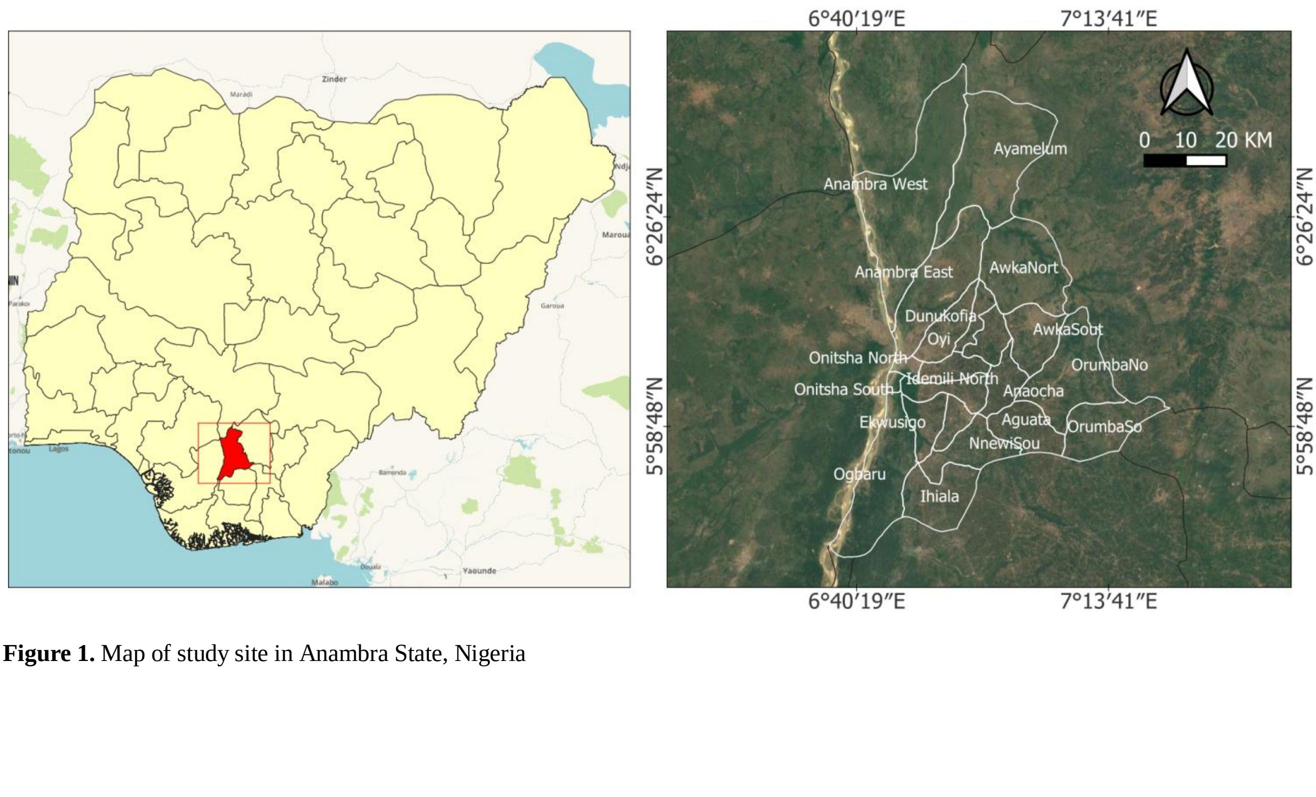

Figure 1. Map of study site in Anambra State, Nigeria

Table 1. Sample distribution of plantain crop farmers

Zones	No. of registered plantain farmers	No. of plantain farmers Sampled	No. of farmers who provided valid responses
Aguata	50	30	18
Anambra	53	32	24
Awka	48	29	20
Onitsha	41	25	14
Total	192	116	76

Sample selection

Multistage sampling technique was used for this study. Multistage sampling is a statistical method that involves selecting samples from a population in multiple stages. It has been used widely in several studies (Emmanuel et al. 2024; Osuji et al. 2024; Igberi et al. 2025). In the first stage, two Local Government Areas (LGAs) were purposively selected from each of the four agricultural zones of the state, namely Aguata, Anambra, Awka, and Onitsha, making 8 LGAs based on their involvement in plantain farming and agricultural activities. The second stage involved a random sample selection of plantain crop farmers from the list of registered farmers in each of the selected LGAs across the four zones of the state. Aguata zone has 50 registered plantain farmers; Anambrahas 53, Awka 48, while Onitshahas 41 registered farmers. This shows that there are unequal numbers and representations of the plantain farmers across the four zones of the state. Hence, an equal sample representation was made from a proportion of 60 percent of the total population from each zone. The sample size for each of the zones were; Aguata 30, Anambra 32, Awka 29, and Onitsha 25. This gave a total of 116 plantain sampled crop farmers across the zones. The list of registered plantain farmers, the proportion of the population sampled, and the valid sample used for the study are shown in Table 1.

Method of data collection

The study was based on primary data collection. Data were obtained with the aid of a structured questionnaire administered to the sampled 116 plantain crop farmers across the four zones of the State. The questionnaire consists of the core objectives of the study, to which the respondents were requested to respond objectively. However, out of the 116 plantain crop farmers, only 76 provided helpful information in line with the study's objectives.

Method of data analysis and model specification

Data were analyzed using descriptive statistical tools such as the mean, frequency, and percentage and econometric tools such as the multivariate probit regression and factor analysis models. The multivariate probit regression model analyzed the factors influencing plantain farmers adoption of climate-smart agricultural practices. It is a statistical and econometric model that simultaneously estimates multiple correlated binary outcomes. It has an advantage over other econometric models in that its application is straightforward and flexible in handling a variety of correlation structures and the interpretability of its parameters. In this study, the multivariate probit regression modeled the dichotomous dependent variable, the various CSA practices adopted by the plantain farmers, and the independent variables. The model is estimated using the maximum likelihood method. The model is expressed as follows:

$Z_{1i} = \propto_1 R_{1i} + \beta_1 H_{1i} + \delta_1 C_{1p} + \varepsilon_{1i}$

$Y_{1i} = 1$ if $Z_{1i} > 0$; $Y_{1i} = 0$ if $Z_{1i} \leq 0$

$Z_{2i} = \propto_2 R_{2i} + \beta_2 H_{2i} + \delta_2 C_{2p} + \varepsilon_{2i}$

$Y_{2i} = 1$ if $Z_{2i} > 0$; $Y_{2i} = 0$ if $Z_{2i} \leq 0$

$Z_{ji} = \propto_j R_{ji} + \beta_j H_{ji} + \delta_j C_{jp} + \varepsilon_{ji}$

$Y_{ji} = 1$ if $Z_{ji} > 0$; $Y_{ji} = 0$ if $Z_{ji} \leq 0$

Empirically, the model is specified as:

$Z_i = \alpha_i X_i$

$Z_i = \alpha_1 X_1 + \alpha_2 X_2 + \alpha_3 X_3 + \alpha_4 X_4 + \alpha_5 X_5 + \alpha_6 X_6 + \alpha_7 X_7 + \alpha_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} + \delta_{11} X_{11} + \delta_{12} X_{12} + \varepsilon_1$

Where:

Z_i = a latent decision variable from which the plantain farmers make choices.

Note that about 11 climate-smart agricultural practices were engaged by the plantain farmers, and this formed the dependent variables and includes:

MF = Mixed farming (Adopted = 1, Not adopted = 0)

MDS = Movement of different sites (Adopted = 1, Not adopted = 0)

PMV = Planting of early maturing variety (Adopted = 1, Not adopted = 0)

CR = Crop rotation (Adopted = 1, Not adopted = 0)

AFM = Application of farm yard manure (Adopted = 1, Not adopted = 0)

ILS = Increased land size cultivated (Adopted = 1, Not adopted = 0)

CPP = Changes in planting period (Adopted = 1, Not adopted = 0)

DNF = Diversification into non-farm activities (Adopted = 1, Not adopted = 0)

CHD = Change in harvesting date (Adopted = 1, Not adopted = 0)

LF = Lengthened fallow (Adopted = 1, Not adopted = 0)

UWF = Use of weather forecast (Adopted = 1, Not adopted = 0)

X_i = represents the independent variables and this includes; $X_{1:}$ Farmer's age (Years); $X_{2:}$ Farmer's gender (1: Male; 0: Female); $X_{3:}$ Farmer's level of education (Years spent in school); $X_{4:}$ Household size (number of persons in a household); $X_{5:}$ Farm size (Ha); $X_{6:}$ Farming experience (Years); $X_{7:}$ Labor (Man-days); $X_{8:}$ Number of extension contacts with the farmer in the cropping year; $X_{9:}$ Total income (Naira); $X_{10:}$ Credit used (Amount borrowed in Naira); $X_{11:}$ Cooperative membership (Yes: 1, No: 0); $X_{12:}$ Victim of climate events (Yes: 1, No: 0); ei: error term

Table 2. Socio-economic characteristics of plantain farmers

Variable	Frequency	Percentage
Age		
21-30	13	17.1
31-40	10	13.2
41-50	28	36.8
51& above	25	32.9
Mean	46	SD=0.06
Sex		
Male	31	40.8
Female	45	59.2
Marital status		
Single	11	14.5
Married	41	53.9
Divorced	12	15.8
Widowed	12	15.8
Level of education		
Primary	30	39.5
Secondary	22	28.9
Tertiary	14	18.4
Non formal	10	13.2
Household size		
1-4	24	31.6
5-8	52	68.4
Mean	7	SD=1.05
Farm size		
0.1-1.0	51	67.1
1.1-2.0	17	22.4
2.1-3.0	08	10.5
Mean	0.8	SD=1.08
Extension contacts		
1-2	34	44.7
3-4	38	50.0
5-6	04	5.3
Mean	3	SD=0.09
Cooperative membership		
Yes	51	67.1
No	25	32.9
Participation in workshop/training		
1-2	27	35.5
3-4	47	61.8
5-6	02	2.6
Mean	3.3	SD=1.02
Farming experience		
1-10	17	22.4
11-20	48	63.2
21-30	11	14.5
Mean	18	SD=1.07
Source of capital		
Banks	08	10.2
Friends/relatives	19	25.0
personal savings	27	35.5
Cooperatives society	12	15.8
Other	10	13.2

RESULTS AND DISCUSSION

Socio-economic characteristics of plantain farmers

Table 2 presents the socio-economic characteristics of plantain farmers. The result shows that 17.1% of the respondents were 21-30 years, 13.2% were 31-40 years, 36.8% were 41-50 years, and 32.9% were 51 years and above. The average age of the respondents was 46 ± 0.06 years. This implies that majority of the plantain farmers were middle-aged, indicating that plantain farming is predominantly carried out by individuals in their prime working years (Zizinga et al. 2022). The sex distribution of plantain farmers shows that 40.8% of the respondents were male while 59.2% were female, indicating that plantain farming is dominated by females, highlighting the significant role of women in the agricultural sector (Zhou et al. 2023). It was observed that the majority, 53.9% of the respondents, were married, while 14.5% were single and the divorced and widowed accounted for 15.8%. This implies that the married farmers provided the needed family labor required to practice climate-smart agriculture in the study area. The result shows that 39.5% of the respondents had primary education, 28.9% had secondary education, 18.4% had tertiary education. However, 13.2% of the respondents had no formal education. This implies that most plantain farmers in the area were literate, significantly influencing their adoption of CSA practices (Zakaria et al. 2020). The study shows that most respondents had a household size of 5-8 persons while the mean household size was 7±1.05 persons. This indicates that majority of the plantain farmers had good number of family members who assisted in plantain farming and implementation of CSA practices. Result indicates that 81.6% of the respondents had farming solely as their occupation, while 18.4% combined farming with other economic activities. This shows that most respondents were farmers, who cultivated plantain using CSA practices (Waaswa et al. 2022).

The farm size shows that majority, 67.1% of the respondents had 0.1-1.0 hectares of land, followed by 22.4% that had 1.1-2.0 hectares of land. The mean farm size was 0.8±1.08 hectares. This indicates that the plantain farmers had limited farm sizes, which can affect their productivity, economies of scale, and access to better inputs and markets (Zhou et al. 2023). Extension contacts result shows that majority, 50% of the respondents had 3-4 extension contacts, and 44.7% had 1-2 extension contacts. The mean extension contacts were 3±0.09, indicating low extension contacts among plantain farmers. This invariably shows limited access to modern innovations and trends disseminated by extension agents. Result shows that majority 67.1% of the plantain farmers belong to a cooperative society, while 32.9% did not associate themselves with any cooperative society. This implies that those that belong to cooperative societies are better off because they obtain various sources of information and variable inputs than those that did not belong to any cooperative society (Vatsa et al. 2023). It was observed that 61.8% of the plantain farmers have participated in workshop/training 3-4 times, while 35.5% have participated 1-2 times. However, only 2.6% of the farmers participated 5-6 times. The mean participation in workshop/training was 3.3±1.02 times. This implies that there has been a low participation in workshop/training among plantain farmers. The majority 63.2% of plantain farmers had 11-20 years of experience in plantain farming. A 22.4% had 1-10 years of experience, while 14.5% had 21-30 years of experience.

The mean farming experience was 18±1.07 years. This shows a high experience level among plantain farmers (Tran et al. 2020). The majority 35.5% of the respondents had personal savings as their major source of capital followed by 25% who agreed that their source of capital was from friends/relatives. It was also observed that there was a low access to credit from banks by plantain farmers in the area.

Level of awareness of farmers to climate smart agricultural practices

Figure 2 shows the level of awareness of farmers to climate smart agricultural practices. The result shows that 39.5% of the farmers were moderately aware of climate smart agricultural practices, 35.5% are sufficiently aware, while 25% of the farmers were not aware of climate-smart agricultural practices. Overall, the study implies that most farmers (75%) have good knowledge of climate smart agricultural practices. Good knowledge and understanding of climate-smart agricultural practices aid farmers in its adoption because most crop farmers are conservative and do not easily respond to new practices unless they are convinced or have seen where such practices were used (Tabe-Ojong et al. 2023). Furthermore, being aware of a particular technique and its adoption/utilization enhance crop yields, outputs and land productivity, improving crop farmers' economic livelihood (Waaswa et al. 2022; Zhou et al. 2023; Yuan et al. 2024).

Climate-smart agricultural practices adopted by plantain farmers

Table 3 shows the CSA practices adopted by the plantain farmers. The farmers mostly adopted the application of farm yard manure. This involves the application of green manure and other domestic wastes to the plantain field; this allows the farmers to sustain higher plantain yield during unfavorable weather conditions such as erratic and destructive winds. Diversification into non-farm activities was ranked second. This practice involves engaging in alternative income-generating activities alongside agriculture. By diversifying their income sources, farmers reduce their dependence on a single crop and mitigate the risks associated with climate change impacts on agricultural production. It provides a buffer against climate-related shocks and contributes to overall household resilience (Khatri-Chhetri et al. 2020; Abigaba et al. 2024).

Mixed farming was ranked third. This involves the practice of crop cultivation and animal husbandry simultaneously. This allows for the sustenance of farmers livelihood in case of any eventuality arising from changes in climate and extreme weather conditions (Shikuku et al. 2017). The planting of early maturing varieties ranked fourth. Early maturing varieties have a shorter growing period, allowing farmers to harvest their plants earlier. This practice helps mitigate the impacts of climate change by reducing exposure to unfavorable weather conditions such as droughts, floods, or extreme temperatures. Early maturing varieties also offer opportunities for better market timing, allowing farmers to take advantage of market demands and achieve higher profits (Omotoso and Omotayo 2024).

The movement to different sites ranked fifth. This involves periodically shifting plantain cultivation to new locations. This practice helps to mitigate the accumulation of pests, diseases, and soil-borne pathogens that can reduce crop productivity. By moving to different sites, farmers can break pest and disease cycles, reduce the reliance on chemical inputs, and maintain the long-term productivity of their plantain farms (Radeny et al. 2022). Changes in harvesting date ranked sixth. This involves adjusting the timing of plantain harvest to adapt to changing climatic conditions. This practice aims to avoid adverse weather events, optimize fruit quality, and minimize post-harvest losses. By shifting the harvest date, farmers can align their activities with favorable weather patterns and reduce the risk of losses due to climate-related factors (Vatsa et al. 2023). The use of weather forecasts ranked seventh. This involves using weather trends to monitor planting and harvesting timelines. This reduces climatic risks, shocks, and other harmful risks associated with climate change.

Lengthened fallow ranked eighth. This involves extending the period between plantain cropping cycles to allow the land to rest and regenerate. Extended fallow periods improve soil fertility, reduce erosion, and promote natural ecosystem functions. This practice helps restore the health of the land and enhances the long-term sustainability of plantain cultivation (Zhou et al. 2023).

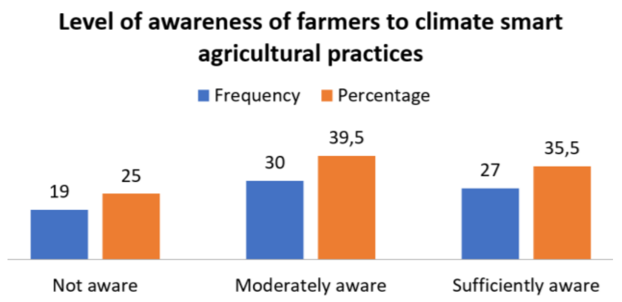

Figure 2. Level of awareness of farmers to climate smart agricultural practices

Table 3. Climate-smart agricultural practices adopted by plantain farmers

CSA practices adopted	Mean	Rank
Application of farm yard manure	93.5	1st
Diversification into non-farm activities	89.1	2nd
Mixed farming	88.7	3rd
Planting of early maturing variety	83.2	4th
Movement to different site	78.1	5th
Changes in harvesting dates	74.6	6th
Use of weather forecasts	72.8	7th
Lengthened fallow	69.8	8th
Change in planting periods	61.4	9th
Crop rotation	58.4	10th
Increased land size cultivated	45.2	11th

Note: Multiple responses

Changes in the planting period tanked ninth. This refers to adjusting the timing of plantain planting to adapt to changing climate conditions. This practice involves planting earlier or later than usual to avoid extreme weather events and optimize plant growth and development. By adapting to changes in the planting period, farmers can enhance plantain production and minimize climate risks such as drought or flooding (Kifle et al. 2022). Crop rotation ranked tenth. This essential CSA practice involves systematically alternating the types of crops grown in a particular field over time. This practice helps to improve soil fertility, reduce pest and disease buildup, and enhance nutrient cycling. By rotating crops, plantain farmers can break pest and disease cycles and optimize soil health, increasing productivity and sustainability in the long run (Mirón et al. 2023). Increasing the land size cultivated ranked least. Expanding the land area under cultivation allows farmers to diversify their production and potentially increase their overall yield. However, land expansion must be done sustainably, considering ecological factors and land management practices to avoid negative impacts on soil health and biodiversity (McNunn al. 2020).

Factors influencing the adoption of climate-smart agricultural practices of plantain farmers

Table 4 shows the factors influencing the adoption of CSA practices of plantain household farmers. The wald chi^2 produced a value of 211.10, which was significant at 1% level and showed the model goodness of fit. The result showed that age, gender, level of education, household size, farm size, farming experience, extension contacts, credit use, and victim of climate events statistically influenced the choice and adoption of various CSA practices. Age was statistically significant and negatively signed for shifting cultivation, crop rotation, and use of weather forecast at 5, 10, and 1% significance levels respectively. This implies that as farmers advance in age, their adoption and use of the various CSA strategies diminishes. Age plays a significant role regarding the adoption of CSA practices. Studies have shown that younger farmers are more likely to adopt CSA practices than aging farmers (Ayeh et al. 2023). The gender coefficient was negatively signed at 5%, 1%, and 10%, respectively for mixed farming, crop rotation, expansion of cultivation and change of harvesting date respectively. This implies that female plantain farmers adopted more CSA practices than male farmers. This is because female farmers are easily persuaded to adopt agricultural practices relative to male farmers, which exhibit indecisiveness when adopting a technology (Martey et al. 2021).

The coefficient of education was also positively signed for planting of early maturing varieties, expansion of cultivation, and change in planting period at 1 and 5% significance levels. This result suggests that as the farmers advance in education, the likelihood of adoption and usage of these practices increases over time. Education is important for the adoption of CSA practices because as farmers acquire more education, they become more exposed to and open-minded to innovations and technologies. Education plays a crucial role in increasing farmers' awareness and understanding of climate change, helping them access relevant information and knowledge about sustainable farming techniques, and encouraging their willingness to embrace innovative technologies (Tabe-Ojong et al. 2023). The coefficient of household size was positively signed at 5, 1, and 10%, respectively for mixed farming, crop rotation, expansion of cultivation, diversification into non-farm activities and the use of weather forecast. This implies that plantain farmers with larger households who provide labor will have higher tendencies to adopt the CSA practices. Studies reveal that large households enhance the adoption and implentation of CSA practices unlike small households (Omotoso and Omotayo 2024). The coefficient of farm size was positively signed at 10 and 5% for mixed farming, application of organic manure and change in planting period respectively. This implies that the larger the farm size, the higher the adoption and use of the CSA practices. Larger farm holdings encourage and support the adoption and usage of CSA practices. This allows for greater input and output resource optimization (Kifle et al. 2022).

The coefficient of farming experience was also positive at 5 and 10% for shifting cultivation, crop rotation and expansion of cultivation, change in planting period and change in harvesting date respectively. This implies that experienced farmers are more likely to adopt these strategies relative to inexperienced farmers. Farming experience plays an important role in knowing the best practices to adopt, when to adopt them, and the resultant benefits of such adoptions (Shikuku et al. 2017). The coefficient of extension visits was positively signed for shifting cultivation, planting of early maturing varieties, application of organic manure, change in planting period and lengthened fallow at 10, 5, and 1% respectively implying that plantain farmers that had extension contacts were more inclined to the adoption and usage of the CSA practices. Extension contacts are very important because farmers are educated on the best practices to use within their available resources. Farmers who had regular extension contacts are more likely to adopt best climate practices which improves yield (Radeny et al. 2022).

The coefficient of credit use was positively signed for mixed farming, planting of early maturing varieties and diversification into non-farming activities at 10% level of significance. This implies that the use of credit resources encourages the adoption of CSA practices. No doubt, these CSA practices might be capital demanding in nature and hence the need for credit support. Credit access plays a crucial role in facilitating the adoption of climate-smart technologies among smallholder farmers (Keil et al. 2021). The coefficient of victim of climate change shows that mixed farming, planting of early maturing varieties, expansion of cultivation, diversification into non-farming activities, lengthened fallow and use of weather forecast were significant at 10, 5, and 1% respectively. This implies that farmers who have experienced negative effects of climate change are most likely to adopt CSA practices unlike farmers who had not experienced climate risks. Studies reveal that farmers who experience adverse climate change effects, such as extreme weather events, are more likely to adopt best adaptive practices to mitigate future climate risks (Waaswa et al. 2022).

Table 4. Factors influencing the adoption of CSA practices of plantain farmers

Variable	MF	MDS	PMV	CR	AFM	ILS	CPP	DNF	CHD	LF	UWF
X_1	-0.9453	-0.6733	-12.7383	-14.8456	-12.9045	-9.9465	-19.0733	-0.0647	-0.0454	-9.0463	-0.0833
	(-0.899)	(-2.752)**	(-0.833)	(-1.853)*	(-0.933)	(-0.451)	(-1.083)	(-1.023)	(-1.235)	(-0.022)	(-4.712)***
X_2	-0.0564	-12.8454	-0.7489	-0.9546	-0.9404	-0.8462	-0.9352	-0.9562	-0.0945	-0.8933	-0.9420
	(-2.7441)**	(-0.954)	(-1.423)	(-3.932)***	(-1.091)	(-1.671)*	(-1.231)	(-1.390)	(-3.213)***	(-0.342)	(-1.222)
X_3	10.8531	0.5673	0.7489	0.7552	8.0464	0.7452	9.4642	0.0534	0.9531	0.8342	0.0734
	(1.002)	(0.344)	(4.032)***	(1.401)	(0.542)	(2.922)**	(3.933)***	(0.921)	(1.423)	(0.721)	(1.023)
X_4	4.0992	0.7489	0.9462	23.9462	0.9648	0.5489	8.0353	2.8421	0.7343	0.9352	3.9347
	(2.941)**	(1.041)	(0.531)	(1.851)*	(1.191)	(2.123)**	(1.423)	(3.634)***	(1.231)	(0.521)	(1.812)*
X_5	0.4674	0.7452	0.8595	0.8451	0.8576	0.3672	0.7342	0.9452	0.0454	0.8351	0.0632
	(1.942)*	(0.642)	(0.621)	(1.201)	(2.621)**	(1.001)	(1.512)*	(1.301)	(0.821)	(1.101)	(0.732)
X_6	9.7843	10.6484	0.0452	0.6758	0.9464	9.3546	0.9341	12.9301	0.8342	2.0733	0.0763
	(1.031)	(2.921)**	(0.233)	(2.122)**	(0.522)	(2.833)**	(1.933)*	(0.521)	(2.481)**	(1.022)	(1.111)
X_7	8.9342	0.74841	0.8462	0.6598	11.9404	0.7489	4.0464	0.0647	0.9453	0.8342	0.0533
	(0.833)	(1.292)	(0.922)	(0.523)	(1.632)	(0.521)	(1.190)	(0.002)	(0.903)	(1.200)	(0.822)
X_8	7.6381	8.9464	0.6490	21.9046	0.9453	3.9454	0.0478	2.9451	3.0533	0.9421	0.8331
	(0.456)	(1.932)*	(2.821)**	(1.026)	(1.920)*	(1.002)	(2.811)**	(0.022)	(0.633)	(3.921)***	(0.422)
X_9	0.5476	0.8453	12.9461	0.8946	5.9464	4.0713	0.0353	0.9523	0.8312	4.9511	0.9422
	(0.961)	(1.099)	(0.099)	(0.061)	(0.056)	(0.410)	(0.821)	(1.311)	(0.521)	(0.612)	(0.001)
X_{10}	0.8657	13.9454	9.0464	0.9468	0.9546	0.7454	0.5562	1.0833	0.0621	0.7331	0.3464
	(1.671)*	(0.833)	(1.900)*	(1.292)	(0.922)	(1.062)	(0.062)	(1.841)*	(0.232)	(0.422)	(0.002)
X_{11}	13.8453	0.8563	0.9357	0.9845	0.6473	0.8321	0.9044	0.0644	0.9533	0.8452	0.9241
	(1.002)	(0.021)	(0.811)	(0.712)	(1.211)	(0.391)	(1.091)	(0.922)	(0.122)	(1.032)	(0.009)
X_{12}	0.7442	0.7842	0.6590	0.5390	9.0341	0.6547	0.0621	0.9452	1.0264	0.0525	0.9532
	(1.934)*	(0.942)	(2.921)**	(1.012)	(0.921)	(1.999)*	(0.123)	(2.021)**	(1.201)	(5.901)***	(1.678)*

Note: Wald chi^2: 211.10***. values in parenthesis are z-values and significant at ***1%, **5% and *10%

Constraints militating against plantain production and CSA practices

Table 5 shows that the major constraints militating against plantain production and CSA practices. These includes problem of capital, problem of soil fertility, lack of technical know-how, poor extension acces, lack of timely information on weather conditions, instability in planting calendar, high cost of inputs and limited lands. The lack of capital was identified as a major constraint against plantain production and adoption of CSA practices. Insufficient financial resources limit farmers ability to practice large scale plantain production and purchase of improved planting materials, organic fertilizers, and other needed inputs, thereby reducing their agricultural productivity. It also frustrates investments in climate-smart agricultural practices in mitigating climate risks (FAO 2022; Fofana et al. 2024). Declining soil fertility can result in reduced crop yields and increased vulnerability to pests and diseases.

Soil fertility management practices, such as organic matter incorporation and balanced nutrient management are crucial for sustaining the long-term productivity of plantain farms. Thus, poor soil fertility can negatively impact plantain production and limit farmers ability to adopt climate-smart agricultural practices (Keil et al. 2021). Limited knowledge and skills in climate-smart agricultural practices can hinder farmers ability to implement appropriate techniques and strategies for climate change adaptation and mitigation. The lack of technical know-how can impede the adoption of CSA practices among plantain farmers, limiting their capacity to effectively respond to climate change challenges (Waaswa et al. 2022). Improving access to extension services is crucial for disseminating knowledge, providing technical support, and promoting the adoption of CSA practices among plantain farmers.

However, limited interaction with extension agents reduces farmers' access to information, training, and guidance on climate-smart agricultural practices, and constraining their ability to adopt and implement CSA practices effectively (Vatsa et al. 2023). Lack of timely information on weather conditions and climate trends limits farmer's ability to make informed decisions regarding their crop cultivation and adoption of appropriate climate-smart agricultural practices. Access to timely information is crucial for farmers to adapt to climate change, make informed decisions, and effectively implement climate-smart strategies. Climate variability and changing weather patterns can disrupt traditional planting schedules, making it difficult and challenging for farmers to determine the optimal time for planting. This constraint affects plantain farm planning, management, and overall productivity.

Consequently, the instability in planting calendar alters plantain production, reducing its market value and frustrates the adoption of CSA practices (Omotoso and Omotayo 2024). The expenses associated with purchasing improved planting materials, fertilizers, pesticides, and other inputs can be a significant barrier for farmers, particularly those with limited financial resources. The high cost of inputs hinders the adoption of climate-smart agricultural practices among plantain farmers. It poses a financial burden and reduces the purchase of necessary inputs. Inadequate land makes the implementations of CSA practices difficult, since most of these practices require large farm holdings to implement, more so, limited land holdings limits large scale plantain production (Zakaria et al. 2020; Ndudzo et al. 2024).

In conclusion, the study findings shows that the plantain farmers were in their productive age, more of female, married, had primary education and household size of 7 persons and relatively. The study revealed a high level of awareness among plantain farmers regarding climate-smart agricultural practices. The most adopted CSA practices included diversification into non-farm activities, crop rotation, planting of early maturing varieties, and changes in harvesting and planting periods. The result showed that age, gender, level of education, household size, farm size, farming experience, extension contacts, credit use and victim of climate events statistically influenced the choice and adoption of various CSA practices. Constraint such as limited capital, poor soil fertility, technical know-how, poor extension access, and lack of timely information on weather conditions hindered plantain production and the adoption of CSA practices. Efforts should be made to provide farmers with training and workshops on climate-smart agricultural practices; this will enhance their knowledge and skills in adopting CSA practices. Research institutions and agricultural agencies should collaborate to provide plantain farmers with up-to-date information on climate change and its variations; this will enhance timely adoption of the CSA practices by the plantain farmers to mitigate adverse effects of climate change.

Table 5. Constraints militating against plantain production and CSA practices

Factorized variable	FC 1	FC 2	FC 3	FC 4
Problem of soil fertility	0.675*			
Instability in planting calendar		0.863*		
Drying of sucker after harvest due to high temperature			0.373	
Lack of timely information on weather conditions				0.678*
Problem of capital	0.783*			
Poor extension access		0.563*		
Inadequate farming land			0.548*	
Erosion occurrence and wind storm				0.274
Shortage of labor force	0.488			
Lack of technical know-how		0.892*		
High cost of fertilizers			0.492	
High cost of inputs				0.784*
Poor attitude of plantain farmers to climate change	0.353			

Note: Extraction Method: Factor component analysis. Rotation Method: Varimax with Kaiser Normalization. *: signifies components with score of 0.5 and above and selected factors

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