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Climate Change Impacts and Adaptation Strategies of Cassava Farmers in Ebonyi State, Nigeria

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Abstract

The study evaluated the climate change impacts and adaptation strategies of cassava farmers in Ebonyi State, Nigeria. Multi-stage sampling was used to select 419 cassava farmers who administered the questionnaire. Data were collected using primary and secondary means and were analysed using mean, frequency, percentage, beta regression model, and ordinary least squares multiple regression techniques. Factors influencing cassava production are meteorological information (95.7%), tradition and culture (94.5%), improved technology utilization (93.1%) and low access to credits (71.8%). Climate change effects on cassava production were reduced biodiversity (95.2%), increased crop failure (97.6%), decreased yield (100%) and increased soil salinity (92.6%). Cassava farmers adapted to various practices such as planting improved cassava varieties (95.9%), insurance (3.3%), planting different crops (96.9%), and livelihood diversification (94.9%).

Age, education, household size, farm size and extension contacts were significant determinants of climate change adaptation strategies of cassava farmers. Variables such as temperature, rainfall, humidity and sunshine had both positive and negative impacts on cassava production. The study recommends cassava farmers seek early warning signals and information on climate change before embarking on their farming operations to avert possible negative consequences.

Introduction

Cassava (Manihot esculenta), after rice and maize, is the third-most significant source of calories in Africa's tropical and subtropical regions (FAO, 2020). It is commonly grown in several Sub-Saharan African nations. Currently, half of the cassava consumed worldwide is produced in Africa (FAO, 2020). Nigeria is the major producer of cassava on a global scale, followed by South-East Asia, Brazil, Indonesia, Thailand, and Vietnam (FAO, 2021). Over 90% of Nigeria's rural families routinely consume cassava. Cassava production in Nigeria has been under the threat of climate change-related events influencing agriculture. Changing climate subject agriculture, especially rain-fed agriculture to danger since it depends on favourable climate conditions to remain productive (Lenis et al., 2020). Presently, negative seasonal variations and changes brought on by climate change pose a threat to cassava output. Cassava production is being impacted by climate change on a global, regional, and local scale (FAO, 2022).

In Nigeria, it has been claimed that climate change has disrupted cassava yields, outputs and quality, causing food shortages and reduced supply. Reduced cassava productivity, for instance, is typically caused by expected changes in extreme weather events, such as temperature increase, change in precipitation pattern, change in relative humidity, windstorm, etc (Kemi and Olusegun 2020). The income and profitability of farmers are impacted by the rapid deterioration of the cassava tubers on the farmland and after harvest (Ekundayo et al., 2021). Less rainfall shrivels cassava tubers that are growing in the soil, causing deterioration and a decrease in size and market value. Rainfall increases spawn a variety of pests and diseases that heavily consume cassava leaves, lowering the photosynthetic activity of cassava plants (Paul et al., 2019). It is reported that Nigeria's cassava crop would continue to decrease as long as climate change persists (Anarah et al., 2019). Nigeria is the sixth least prepared to adapt to climate change and the 53rd most vulnerable nation, according to the 2021 Notre Dame Global Adaptation Index (ND-Gain Country Index, 2021).

This necessitates a comprehensive strategy and a thorough process of raising awareness among Nigerian rural farming households on how to adapt to climate change (FMARD, 2021). To make up for lost ground in the global adaptation index, Nigeria urgently needs to embrace tried-and-true adaptation solutions. These strategies are known to scale up cassava production and mitigate climate change sternly (Susanto et al., 2020). In recent times, cassava farmers in Ebonyi State have experienced a severe decline in cassava production resulting in decreased yields, reduced quality, and quantity as well as loss in economic value and market return, thereby subjecting them to hunger, starvation, poverty and economic hardship (Igberi et al., 2022). Their land productivity is seriously threatened unprecedented changes in climate variation.

Currently, the growing population in the state is driving up the demand for food production, and cassava being a significant homemade crop is struggling to keep up as crop yield decreases intensely due to adverse climatic conditions prevalent in the state (Onyeneke et al., 2021). Addressing these disturbing issues informed the research gap and motivation for the study in the State.

Methodology

The study was executed in Ebonyi State, Nigeria. The State was picked because of its extensive cassava farming and rural lifestyle. About 13 LGAs make up Ebonyi State. The National Population Commission, Abuja, estimates the state's population to be 2,176,947 people in 2006 (NPC, 2007). The total land area is about 5,533 km^2 with *Latitude*: 6°10' 40.7028" and *Longitude*: 7°57' 33.4296".

Multi-stage sampling technique was employed for sample selection. In the first stage, four local government areas (LGA's) were randomly drawn from each of the agricultural zones of the state; (Ebonyi North, Ebonyi South, and Ebonyi Central), to make 12 LGA's. In the second stage, four communities were randomly selected from the LGAs, making a total of 48 communities. In the third stage, two villages were randomly picked from the selected communities giving 96 villages. The fourth stage had 5 cassava farmers randomly selected, giving a total of 480 cassava farmers. The list of the registered cassava farmers obtained from the state agricultural development programme formed the sample frame.

A questionnaire was used for primary data collection and 419 questionnaires were found useful for data analysis. Data collected were analysed using percentage, beta regression model and ordinary least square multiple regression techniques. The beta regression model was used to analyse the determinants of cassava farmers' adaptation to climate change. The ordinary least squares multiple regression technique was used to analyse climate change impacts on cassava production.

Beta regression model is defined as follows;

$$g(\mu_i) = X_i^T \beta + r_i = \acute{\eta}_i \qquad \text{eqn. 1}$$

Where,

$\beta = (\beta_1 \ldots\ldots \beta_k)^T$ is a k x 1 vector of unknown regression parameters (k < n), $X_i = (x_{i1} \ldots\ldots x_{ik})^T$ is the vector of k regressors or (independent variables or covariates and $\acute{\eta}_i$ is a linear predictor for the ith observation, i.e. ($\acute{\eta}_i = \{\beta_1 x_{i1} + \beta_k x_{ik}\}$, usually $x_{i1} = 1$; for all i, accommodating intercept and n is the sample size. Here g (.): (0, 1) - IR is a link function which connects the linear predictor and the response variable. Thus, the beta regression logit link function is expressed as;

$g(\mu) = \log \mu / (1-\mu)$ eqn. 2

The log likelihood of the beta regression model is estimated thus,

$L_i(\mu_i, \varphi) = \log \Gamma(\varphi) - \log \Gamma(\mu_i \varphi) - \log \Gamma(1-\mu_i)\varphi\} + (\mu_i \varphi - 1)\log y_i + \{1-\mu_i)\varphi - 1\}\log(1-y_i)$

eqn. 3

Note that, $\mu_i = g^{-1} X\frac{T}{1}\beta$ is a function of β, the vector of regression parameters, thus

$CCA_{SCF} = g(\mu_i) = X_i^T \beta + r_i = \eta_i$ eqn. 4

In this study, the parameter estimation is performed by the maximum likelihood (ML) of the beta regression model, thus the response and independent variables are explicitly specified as follows;

CCA_{SCF} = Climate change adaptation strategies of cassava farmers (Proportion of adoption of the ith cassava farmers)

B = Vector of unknown coefficients

r_i = Error term, assumed to be independently distributed with mean zero and constant variance

X_i = Vector of independent variables; which include;

X_1 = Age of farmer (Years)

X_2= Gender (Male 1, 0 Female)

X_3= Household size (No. of persons)

X_4 = Farm size (Ha)

X_5= Education (No. of years spent in school)

X_6= Farming experience (No. of years)

X_7= Marital status (married 1, 0 Single)

X_8= Cooperative membership (Yes 1, No 0)

X_9= Extension contact (No. of visits)

X_{10}= Occupation (Farming 1, 0 otherwise)

e = error term

The ordinary least square multiple regression techniques was expressed as follows;

$Y = f(X_1, X_2, X_3, X_4, X_5, X_6) + e$ eqn. 5

Where

Y = Cassava yield (kg)

X_1 = Temperature (^{0}c)

X_2 = Rainfall (mm)

X_3 = Number of rainy days (number of times)

X_4 = Evaporation rate (mm)

X_5 = Sunshine hours (hours)

X_6 = Relative humidity (%)

e = error term

Results and Discussion

Factors influencing cassava production

The factors influencing the production of cassava are presented in Table 1. Meteorological information was indicated by 95.7% of the cassava farmers, which implies that meteorological information influences cassava production. Climate change information such as early warning signals enhances cassava production (Onyeneke et al., 2020). This information positions farmers to plan ahead and re-strategize their farming operations in order to mitigate adverse climatic effects and to increase farm production. Tradition and culture were reported by 94.5% of the cassava farmers. This implies that tradition and culture poses a great influence on the production of cassava (Kogo et al., 2020). For instance, cassava farmers in the study area indicated that their traditions and customs forbid them from engaging in farming activities on certain days. Improved technology utilization was indicated by 93.1% of the cassava farmers, which implies that technological innovation enhances large-scale cassava production. Low access to credit was reported by 71.8% of the cassava farmers, this means that poor access to capital could hinder the extensive production of cassava. Access to land was indicated by 95.2% of the cassava farmers. This implies that more access to land could enhance cassava production while limited access mars it (Igberi et al., 2022). The Table shows that about 89.9% of the cassava farmers indicated land tenure systems; this implies that the system of land tenure ownerships and control determines to a great extent, the level of cassava production which could be attained (Onyeneke et al., 2020).

Table 1: Factors influencing cassava production

Factors	Percentage
Meteorological Information	95.7
Tradition & Culture	94.5
Improved technology Utilization	93.1
Low Access to Credits	71.8
Access to Land	95.2
Land Tenure Systems	89.9

Source: Field survey data, 2021

Climate change effects on cassava production

The climate change hazards influencing cassava production among farmers is presented in Table 2. The result reveals that climate change had severe effects on cassava production. A reduced level of biodiversity was attested by 95.2% of the cassava farmers, which suggests that the State's climate change significantly hindered the biodiversity of cassava. Poor yield, quantity, and quality, and low-value chain additions were adverse effects of the reduced biodiversity of cassava (Chandio et al., 2020). Most cassava farmers—97.6%—complained of crop failure brought on by the excesses of climate change. Climate change undoubtedly has a significant role in crop failure, which might happen from time to time and this frustrates cassava farmers' efforts that cannot be recouped (Susanto et al., 2020 and Onyeneke et al., 2021). Also, 95.7% of the cassava farmers reported higher levels of water logging. This implies that ter logs initiate growth of cassava diseases, pests, and insect infestations resulting in low yield and harvest (Ogunpaimo et al., 2020). About 92.6% of the cassava farmers complained of increased soil salinity, which has a negative impact on planted cassava crops. Too many salts in the root zone limit cassava growth. All of the cassava producers in the state reported decreased yield. Low cassava yield seem to be one of the most severe effects of climate change which poses a serious danger to farmers globally (Adeleke et al., 2021). It is undeniable that climate change causes cassava producers to produce less, which results in increased shortage of food as witnessed by 99.3%. About 88.5% of the cassava farmers reported increased insect infestation, indicating that climate change enhanced insect infestation through water logging and percolations (Pipitpukdee et al., 2020). Moreover, 91.6% of the cassava farmers' reported increased erosion to have impacted their cassava production negatively. About 93.1% of the farmers reported scarcity of irrigation water due to prolonged rainfall; this negatively impacted their cassava output (Adejuwon and Ogundiminegha, 2019). About 90.9% of the cassava producers reported decreased soil fertility. This results from water/erosion runoffs depleting the soil of its vegetative nutrients and mineral compositions. The fact that more than 95.0% of cassava farmers reported increasing crop disease suggests that climate change is a factor in cassava disease distribution and intensification. Decreased economic returns were reported by 96.4% of the cassava farmers. This is associated with poor and low yield of cassava production, which severely affects economic returns (FAO, 2021).

Table 2: Climate change effects on cassava production

Climate change hazards	Percentage
Reduced biodiversity	95.2
Increased crop failure	97.6
Increased water logging condition	95.7
Increased soil salinity	92.6
Decreased yield	100
Increased food shortage	99.3
Increased insect infestations	88.5
Increased erosion menace	91.6
Scarcity of irrigation water	93.1
Reduced soil fertility	90.9
Increased disease of crop	96.7
Decreased economic returns	96.4

Source: Field survey data, 2021

Cassava farmers' adaptation strategies

The results of cassava farmers' adaptation strategy are presented in Table 3. The result demonstrated that 95.9% of the farmers adopted planting improved cassava varieties. Improved varieties of cassava have proven to be efficient in terms of yield, quality, and resistance to pests and diseases (FAO, 2020). Insuring their farms against unforeseen climatic events was done by about 3.3% of the cassava producers. As long as climate change continues, farming will be subject to inherent risks from fire disasters, and insect and disease attacks (FAO, 2021). About 96.9% of farmers who grow cassava do so in combination with other crops. Multiple crop planting is used as a mitigation and adaptation method in overcoming negative climatic effects (FAO, 2022).

About 94.9% of the cassava farmers practised livelihood diversification, which meant that they had other sources of income in addition to cassava cultivation. Soil and water conservation techniques were practised by 93.3% of the cassava farmers. This technique shields the topsoil from erosion runoffs and prevents overflooding of cassava crops (Lenis et al., 2020). Again, 95.7% of the cassava growers adjusted their planting and harvesting dates due to changing climate antecedents. Thus, cassava producers are compelled to modify their planting and harvesting dates to accommodate the current weather conditions occurring regularly (Kemi and Olusegun, 2020). Irrigation was used by about 90.2% of cassava producers. Irrigation is often the artificial delivery and/or application of water to farmlands in order to ensure water availability and supplies all year round (Onyeneke et al., 2021). About 94.0% of the farmers rely on climatic data and projections. This enables the farmers to strategically plan their farming activities to avoid losses.

About 95.2% of cassava farmers adapted to extension agents' advice and direction, these focus on new and improved cultivation techniques, fertilizer application techniques, improved cassava varieties, etc (Ekundayo et al., 2021). Once more, 97.4% of the producers used fertilizers in the right amounts. It should be emphasized that increasing cassava yield in this period of climate change has been successfully accomplished by applying both organic and inorganic fertilizers (Paul et al., 2019). Again, 97.4% of the cassava farmers adopted efficient and effective use of insecticides. Insects, rodents, and other pests that damage field-grown cassava crops can be prevented by making efficient and effective use of insecticides. Consequently, 47.9% of the cassava producers reported greater land access. This adaption strategy was due to land fragmentation problems that prevent large-scale cassava farming (Anarah et al., 2019). Erosion control measures were adopted by 96.4% of the cassava farmers, this implies that the cassava farmers took to erosion control measures to prevent the erosion of the vegetative soil surface, newly planted cassava stems, mulch materials and manure applications.

Table 3: Cassava farmers' adaptation strategies

Adaptation strategies	Percentage
Planting improved cassava varieties	95.9
Insurance	3.3
Planting different crops	96.9
Livelihood diversification	94.9
Soil and water conservation techniques	93.3
Adjusting planting and harvesting dates	95.7
Irrigation	90.2
Reliance on climate information and forecasts	94.0
Collaboration with extension workers/agents	95.2
Appropriate application of fertilizer	97.1
Efficient and effective use of pesticide	97.4
Increased land access	47.9
Erosion control measures	96.4

Source: Field survey data, 2021

Determinants of cassava farmers' adaptation to climate change

The maximum likelihood determinants of cassava farmers' adaptation to climate change are presented in Table 4. The Pseudo (R^2) value was 0.8209, indicating that about 82% of the (R^2) validated the model fitness. The Log likelihood value of 181.770 was highly significant; implying that the exogenous variables investigated influenced the endogenous variable (adaptation). The age of the cassava farmers was negative and significant, which indicates that their ability to adapt to climate change was negatively related to their age. This means that as cassava farmers get older, their ability to adjust to climate change decrease, making them more vulnerable (Susanto et al., 2020). The household size coefficient was positive and statistically significant, which suggests that as household size increases among cassava growers, so does the amount of family effort put into coping with climate change (Raju, 2019). The coefficient of farm size was positive and significant, suggesting that a 1% increase in cassava farmers' farms will correlate to about 929.4% increase in their adaptation propensity to climate change (Onyeneke et al., 2021). The education coefficient was positive and statistically significant, suggesting that higher educational levels boost the capacity of cassava farmers to adapt to climate change (Kogo et al., 2020). The coefficient of farming experience was positive and significant, indicating that a 1% increase in farming experience is likely to increase farmers’ adaptation propensity by 434.5%. The extension contact was positive and significant, suggesting that an increase in these interactions will result in an increase in farmers' adaptive tendencies (FAO, 2021).

Table 4: Maximum likelihood determinants of cassava farmers' adaptation to climate change

Variables	Coefficients	Z-values	Std. Error
Constant	-0.88646	-0.77909	1.13781
Age	-4.80342	-1.61160*	2.98052
Gender	0.66602	1.09943	0.60578
Household size	0.77329	2.55051*	3.03190
Farm size	0.92939	3.80041*	0.24454
Education	5.75762	4.22042*	1.36422
Farming experience	4.34446	4.70303*	0.92375
Marital status	-0.88484	-1.45070	0.60994
Cooperative membership	1.44743	1.20041	1.20577
Extension contacts	4.47782	3.70116*	1.20984
Occupation	-0.23242	-1.00360	0.23158
Log likelihood	181.770*		
Pseudo (R^2)	0.8209		
N	419		

Climate Change Impacts on Cassava Production

The Impacts of climate change on cassava production are presented in Table 5. The model of ordinary least square regression was used. Given its number of significant variables, highest F-value, and highest R^2, the double-log functional form provided the best match. The R^2 value of 0.9401 indicated that 94% of the total variations in the endogenous variable were explained by the climate variables observed. The temperature was significantly negative, indicating that cassava yield is decreased by rising temperature. The development of the cassava mosaic disease is bred by an increase in soil temperature; this affects cassava yield, income, and sustainable production. High temperatures hinder the growth of cassava roots, shoots, and tubers, impairing plant height and root extensions (Ikuemonisan et al., 2020). Rainfall was negative and significant, suggesting that excessive rainfall lowers yield of cassava via soil erosion, water logging, and percolation, resulting in stunted growth. Increased rainfall poses possible risks to the development of cassava crops as newly planted cassava stems are eroded leading to casualties (Chandio et al., 2020). Excess rainfall initiates floods, which erode the entire cassava farm land resulting in total crop failure, food deficit and insecurity. The number of wet days was negative and significant; indicating that an increase in the number of rainy days lowers cassava yield via heavy

Table 5: Climate change impacts on cassava crop production

Variable	Linear	Semi-log	Double-log	Exponential
Constant	7703.01	43.0011	43.213	10.9005
	(1.301)	(3.710)***	(1.000)	(1.022)
Temperature (X_1)	-4.4130	-5.5011	-6106.09	-6.0610
	(-1.132)	(-3.101)***	(-2.771)**	(-1.002)
Rainfall (X_2)	-501.002	-14.003	-394.018	-90.487
	(-2.311)**	(-1.082)	(-3.550)***	(-1.400)
Number of rainy days (X_3)	-12.2121	-5.1505	-5173.25	-41.011
	(-1.403)	(-1.311)	(-4.401)***	(-0.004)
Evaporation rate (X_4)	-7072.02	-40.011	-6804.47	-72.3045
	(-1.012)	(-1.812)*	(-1.201)	(-5.925)***
Sunshine hours (X_5)	162.352	4.9021	30157.09	7.4718
	(4.320) ***	(1.208)	(4.600)***	(1.502)
Relative humidity (X_6)	505.831	7.521	9110.81	7.0042
	(1.313)	(1.200)	(4.904)***	(1.309)
R^2	0.7001	0.8091	0.9401	0.6901
F- ratio	7.909***	12.001***	66.04***	10.422***

Source: Field data, 2021 ***P≤001, **P≤005.

flooding of cassava farmlands and wearing away the top vegetative soil layers (Pipitpukdee et al., 2020). It also reduces the soil's fertility and productivity, which lowers cassava yield and quality. An increase in rainy days also encourages the growth of cassava pests, insects and diseases that attack cassava plants leading to poor growth (Adejuwon and Ogundiminegha, 2019). The number of sunshine hours was significant and positive, indicating that a percentage increase in sunshine hours boosts cassava yield and output. Sunshine promotes the photosynthetic activities of cassava plants, which results in sustainable yield and output (FAO, 2020). For crops to thrive and operate at their best, sunlight is required as it aids in the build-up of soil's biodiversity and microbial soil organisms. Relative humidity was significant and positive, indicating that a 1% rise in relative humidity will lead to a 911% rise in cassava yield. Relative humidity raises the moisture content of farmlands, especially during dry seasons, leading to a rise in the yield of cassava (Susanto et al., 2020). Relative humidity supports cassava water relations (transpiration), growth of greenish leaves, roots, and shoots, as well as their overall development. Additionally, it improves photosynthesis, crop pollination, stem germination, and soil-water aeration at all times.

Conclusion and Recommendation

Effects of climate change on cassava production manifest in increased erosion menace, scarcity of irrigation water, reduced soil fertility, increased disease of crop and decreased economic returns of cassava farmers. Thus, farmers in a bid to adapt to climate change and mitigate these adverse effects adopted various climate change adaptation strategies such as soil and water conservation techniques, adjusting planting and harvesting dates, irrigation, reliance on climate information and forecasts and collaboration with extension workers/agents. Determinants of climate change adaptation strategies of cassava farmers were age, education, household size, farm size, farming experience and extension contacts. Temperature, rainfall, humidity, number of rainy days and sunshine hours were significant climatic variables influencing cassava production in the state. Cassava farmers seek early warning signals and information on climate change before embarking on their farming operations to avert possible negative consequences that may arise in the course of their farm production and agricultural activities.

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