doi:10.14720/aas.2025.121.4.22984 Original research article / izvirni znanstveni članek

Assessing the Impact of Climate Change on Groundnut Production in Nigeria

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Received July 02, 2025. Accepted November 19, 2025
Delo je prispelo 2. julij 2025, sprejeto 19. november 2025

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Abstract: The study assessed the impact of climate change on groundnut (*Arachis hypogaea*) production in Ebonyi State, Nigeria. A total of 351 groundnut farmers were purposively selected for the study. Primary data were obtained through structured questionnaires and analyzed using descriptive statistics, multiple regression analysis, and a beta regression model. Climate change had significant adverse effects on groundnut production, including stunted plant growth ($P < 0.01$), increased pest and disease outbreaks ($P < 0.01$), and reduced land productivity ($P < 0.05$). The predominant adaptation strategies employed by farmers were use of improved groundnut varieties (100%), mixed cropping (85.8%), and livelihood diversification (99.1%). Factors significantly influencing adaptation capacity were age ($P < 0.01$), education ($P < 0.01$), household size ($P < 0.05$), and access to capital ($P < 0.01$). Major constraints to adaptation included inadequate capital (99.7%), distant farmlands (77.2%), and high labor cost (90.8%). The study concludes that climate change poses serious threats to groundnut production and rural livelihoods in Ebonyi State. It recommends increased investment in climate policy financing, establishment of localized climate information centers, and the promotion of climate-smart agricultural practices to strengthen farmers' resilience and minimize climate-induced losses.

Key words: Climate change impacts, groundnut production, adaptation strategies

Ocena uničujočega vpliva podnebnih sprememb na proizvodnjo arašidov v Nigeriji

Izvleček: Rezultati raziskave so pokazali, da so pridelovalci arašidov večinoma ženske (57,3 %), poročene (51,9 %) in v gospodinjstvu s 7 osebami. Podnebne spremembe so negativno vplivale na pridelek arašidov, kar je povzročilo upočasnjeno rast ($p < -0,01$), izbruhe škodljivcev in bolezni ($p < -0,01$), zmanjšanje donosa površin ($p < -0,05$) in dohodka kmetij ($p < -0,01$). Setev izboljšanih sort arašidov (100 %), gojenje več poljščin (85,8 %) in diverzifikacija preživetja (99,1 %) so bile prilagoditvene strategije za ublažitev podnebnih vplivov pri pridelovanju arašidov. Starost ($p < 0,01$), izobrazba ($p < 0,01$), velikost gospodinjstva ($p < 0,05$), dostop do kapitala ($p < 0,01$) in iskanje zgodnjih informacij o podnebnih spremembah ($p < 0,01$) so bili pomembni dejavniki prilagajanja. Neustrezen kapital (99,7 %), oddaljenost kmetijskih zemljišč (77,2 %), visoki stroški dela in majhna razpoložljivost delovne sile (90,8 %) ter tehnična uporaba nekaterih strategij prilagajanja (74,1 %) so omejevali strategije prilagajanja podnebnim spremembam. Raziskava priporoča financiranje podnebne politike in razvoj lokalnih centrov za podnebne napovedi ter sprejetje podnebno pametnih kmetijskih praks za preprečitev škodljivih učinkov.**Ključne besede:** vplivi, podnebne spremembe, pridelava arašidov, gospodinjstva**.**

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1 INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is an important leguminous and cash crop predominantly cultivated in northern Nigeria and several other states across the country. It is grown by both smallholder and commercial farmers and serves as a key source of food, income, and livelihoods. Nigeria remains the largest producer of groundnut in Africa, accounting for about 39% of the continent's total production and ranking third globally after China and India (FAO, 2024). The country currently produces approximately 2 million metric tons of groundnut, representing about 5% of global output (FAO, 2024). Groundnut is rich in protein, serves as a major source of edible oil, and provides nutritious fodder for livestock (FAO, 2023). It occupies about 34% of Nigeria's total cultivated land area and contributes roughly 23% to household earnings nationwide (FAO, 2022). Groundnut production in Sub-Saharan Africa, including Nigeria, is heavily dependent on climatic conditions—particularly rainfall and temperature. According to Ezihe et al. (2017), the increasing unpredictability of these factors has exacerbated production risks, leading to substantial declines in yield, output, and profit margins. Other climatic variables such as relative humidity, atmospheric pressure, and wind speed have also recently shown significant influence on crop growth and productivity. The reality of climate change is now undeniable, with its consequences being felt globally (Kadiyala et al., 2021). In Nigeria, the manifestations of climate change—rising temperatures, erratic rainfall, sea level rise, flooding, drought, desertification, land degradation, and more frequent extreme weather events—have severely disrupted agricultural production, exacerbating food shortages and food insecurity (FAO, 2022). Rainfall intensity has increased, resulting in flash floods and runoff across several states, a trend projected to worsen in coming years (Ajayi et al., 2020; Neelima et al., 2023). Similarly, rising temperatures are adversely affecting soil fertility, plant growth, and crop yields.

In recent years, groundnut production in Nigeria has been increasingly vulnerable to these climatic changes, resulting in declining yields and economic returns (Kemi et al., 2021). As a weather-sensitive crop, groundnut responds sharply to fluctuations in temperature, humidity, and rainfall. Elevated temperatures and humidity foster pest and disease infestations, while excessive rainfall often causes erosion and flooding of farmlands, leading to crop failure (Kadiyala et al., 2021; Neelima et al., 2023). High evaporation rates deplete soil moisture and aeration, disrupt water balance during germination and growth, and consequently reduce yield (Obedgiu et al., 2024; Tabe-Ojong et al., 2023). Similarly, increased relative humidity impairs photosynthesis, limits leaf emergence, and stunts plant growth (Mabhaudhi et al., 2018). High atmospheric pressure negatively affects seed germination, root development, and shoot formation, while severe windstorms uproot plants, damage root systems, and expose crops to pest and disease attacks, culminating in reduced productivity (Carr et al., 2022; FAO, 2023). These adverse climatic conditions are now evident in regions such as Ebonyi State, Nigeria, where groundnut farmers are facing significant yield losses and economic hardships. Climate-induced stressors have jeopardized farmers' efforts, depleted their resources, and undermined their means of livelihood and sustenance.

Although extensive studies have investigated the effects of climate change on agricultural production in Africa, most have concentrated on cereal crops such as rice, millet, wheat, and sorghum (Msowoya et al., 2016; Guna et al., 2019; Olufemi et al., 2020; Bekuma et al., 2022; Yasin et al., 2022; Onyeneke et al., 2022; Alimagham et al., 2024). Similarly, other research has focused on tuber crops including cassava, yam, and potato (Tajudeen et al., 2022; Tetteh et al., 2022; Egbaji & Anyaorah, 2023; Otegbayo et al., 2024; Kumar et al., 2024; Okereke & Okereke, 2024) and on vegetable crops such as okra, tomato, and *Telfairia occidentalis* (Onyemuwa et al., 2017; Dike et al., 2020; Osuji et al., 2022a; Snoek et al., 2022; Ofuya et al., 2023; Alabi, 2024; Mdimi et al., 2024). Despite the economic and nutritional significance of groundnut (*Arachis hypogaea* L.), empirical studies assessing its vulnerability to climate change remain limited, particularly in Ebonyi State. The absence of focused research on groundnut farming in Ebonyi State presents a critical gap in both academic literature and agricultural policy. Groundnut serves as an essential source of household income, and supports rural food security. Yet, its production is increasingly threatened by climatic stressors such as erratic rainfall, extreme temperatures, and pest infestations. The neglect of this crop in prior climate-related studies has limited understanding of its specific climatic sensitivities and the adaptive responses required to sustain production under changing environmental conditions. Addressing this gap, the present study isolates and examines the perceived and measurable effects of climate change on groundnut cultivation in Ebonyi State, Nigeria. This localized assessment provides a more nuanced understanding of how climatic variables—including temperature, rainfall, humidity, wind, and evaporation—interact to influence yield, quality, and farmer livelihoods. The rationale for this study lies in Nigeria's increasing vulnerability to climate change and the urgent need to develop crop-specific adaptation frameworks. A clear understanding of the climate–groundnut nexus will enable farmers, researchers, and policymakers to implement effective climate-smart agricultural practices and enhance production resilience. The novelty of this study stems from its unique focus on groundnut—a relatively under-researched but economically significant crop—and from its integration of biophysical and socioeconomic perspectives in evaluating climate impacts. Unlike previous studies that examined aggregate agricultural sectors, this research provides empirical evidence on a single crop's response to climatic variability, thus offering a targeted foundation for policy interventions, financing mechanisms, and adaptive strategies aimed at revitalizing groundnut production in Nigeria.

2 MATERIALS AND METHODS

The study was conducted in Ebonyi State, Nigeria, one of the major agrarian states in the southeastern region of the country. The state is characterized by vast agricultural land resources and a predominantly farming population, accounting for approximately 70 % of its total inhabitants. Ebonyi State comprises 13 Local Government Areas (LGAs) with an estimated population of 3,242,500 people, and is geographically located between latitude 6°10'40.70''N and longitude 7°57'33.42''E. A purposive and multi-stage sampling technique was employed in selecting respondents (groundnut farmers). In the first stage, four LGAs known for intensive groundnut cultivation were purposively selected from the thirteen LGAs. In the second stage, four autonomous communities engaged in groundnut production were randomly selected from each of the chosen LGAs, resulting in sixteen communities. In the third stage, four villages were randomly selected from each community, making a total of sixty-four villages. Finally, in the fourth stage, six groundnut farmers were randomly selected from each village, giving a sample size of 384 respondents. However, only 351 questionnaires were correctly completed and found valid for analysis. Data were analyzed using descriptive statistics (mean, frequency counts, and percentages), multiple regression analysis, and the beta regression model. The multiple regression model was used to examine the perceived impacts of climate change on groundnut yield, offering a comprehensive and robust assessment of relationships by considering multiple explanatory variables and controlling for potential confounders. This approach provided more reliable and accurate insights into the endogenous variable interactions. The beta regression model was employed to identify the determinants influencing farmers' adaptation strategies to climate change. This model is particularly appropriate for analyzing bounded continuous variables, such as proportions and percentages. Its flexibility, capacity to handle heteroskedasticity, and ease of interpretability make it a superior alternative to standard linear regression models in many real-world agricultural and socio-economic studies. The multiple regression analysis was estimated as follows;

$$Y = f(X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, X_{10}, X_{11}, X_{12}, X_{13}, ei) \ldots\ldots\ldots\ldots\ldots \text{ eqn. 1}$$

Where

Y = Groundnut yield (Kg ha^{-1})

X_1 = Experienced poor/stunted growth rate (Yes = 1, No = 0)

X_2 = Experienced pest and disease outbreaks (Yes = 1, No = 0)

X_3 = Experienced reduction in land yield (Yes = 1, No = 0)

X_4 = Experienced reduction in farm income (Yes = 1, No = 0)

X_5 = Experienced severe poverty (Yes = 1, No = 0)

X_6 = Experienced increased rainfall intensity (Yes =1, No = 0)

X_7 = Experienced prolonged dry season (Yes = 1, No = 0)

X_8 = Experienced frequent floods (Yes = 1, No = 0)

X_9 = Experienced increased temperature (Yes = 1, No = 0)

X_{10} = Experienced severe windstorm (Yes =1, No =0)

X_{11} = Experienced unpredictability of rainfall (Yes = 1, No = 0)

X_{12} = Experienced late onset rain (Yes = 1, No = 0)

X_{13} = Experienced early cessation of rain (Yes = 1, No = 0)

ei = error term

2.1 QUESTIONNAIRE DESIGN AND ITEM DEVELOPMENT

The questionnaire was designed based on a thorough review of relevant literature and previously validated instruments on climate change studies, groundnut production, climate adaptation, etc. Items were developed to capture key constructs such as farmers' socioeconomic characteristics, perceived impacts of climate change, adaptation strategies, etc. A pretest of the questionnaire was conducted with a small sample of 15–20 farmers from a community similar to the study area. Feedback from the pretest was used to refine ambiguous or unclear items, ensuring that questions were contextually appropriate and easily understood by respondents.

2.1.1 Validity Checks

Content validity was established through expert review. Three agricultural extension specialists and two climate change and social science researchers evaluated the items for relevance, clarity, and coverage of the intended constructs.

Construct validity was examined using exploratory factor analysis (EFA) to ensure that items loaded appropriately on their intended dimensions.

Reliability testing

The internal consistency of each construct was assessed using Cronbach's alpha, with reliability coefficients ranging between 0.72 and 0.85, indicating acceptable to high reliability.

Final instrumen

The final version of the questionnaire, which was designed to address the study's objectives, was administered to the selected respondents through close monitoring, regular follow-up, and continuous evaluation to ensure a high response rate and data quality.

Given that the dataset comprised climate- and weather-related variables representing farmers' experiences—measured as binary indicators—the possibility of high intercorrelation among the explanatory variables (multicollinearity) was anticipated. To address this, the researchers conducted a Variance Inflation Factor (VIF) diagnostic test to detect the presence and extent of multicollinearity among the independent variables. The results revealed that all explanatory variables had VIF values below 5 (VIF < 5), indicating the absence of severe multicollinearity. This threshold is widely considered acceptable in econometric literature, and therefore, the model was deemed statistically reliable for the study.

The beta regression model is specified as follows;

$$Y = f(b_i X_1 + b_2 X_2 + b_3 X_3 + b_4 X_4 + b_5 X_5 + b_6 X_6 + b_7 X_7 + b_8 X_8 + b_9 X_9 + b_{10} X_{10}) + ei \qquad \text{eqn. 2}$$

Where

Y = Adaptation strategies; defined as n/m

n = Actual number of adaptation strategies used per groundnut farmers

m = Total number of adaptation strategies available for the groundnut farmers

X_1= Age of farmer (Years)

X_2= Education (Number of years spent in school)

X_3= Household size (Number of persons)

X_4= Access to capital (Naira)

X_5= Farming experience (Number of years)

X_6= Farm size (Hectare)

X_7= Access to early climate change information (Yes = 1, No = 0)

X_8= Participation in climate change training and workshops (Yes = 1, No = 0)

X_9= Experienced adverse climate events (Yes = 1, No = 0)

X_{10}= Access to agricultural extension services (Number of visits)

ei = error term

3 RESULTS AND DISCUSSION

3.1 SOCIO-ECONOMIC CHARACTERISTICS OF GROUNDNUT FARMERS

Table 1 presents the socioeconomic characteristics of the groundnut farmers. The results show that the majority (47.0 %) of the farmers were within the age range of 41–50 years. The mean age of 48 years suggests that most farmers were in their active and productive years, capable of sustaining labor-intensive groundnut farming (Wei et al., 2022). Gender distribution reveals that 42.7 % of the farmers were male, while 57.3 % were female, indicating female dominance in groundnut production. This could be attributed to the engagement of men in other labor-intensive crops such as yam, leaving groundnut cultivation largely to women (Ali et al., 2017). Marital status analysis shows that 51.9 % of the respondents were married, 37.6 % were single, and 10.6 % were divorced or widowed. The higher proportion of married farmers implies the advantage of readily available family labor, which enhances farm operations and reduces labor costs. Regarding educational attainment, 37.9 % of the respondents had secondary education, 31.6 % had primary education, 5.4 % had tertiary education, and 25.1 % had no formal education. This indicates that a majority of the farmers were literate and, therefore, more likely to understand and apply agricultural innovations and climate information for improved productivity (Olanrewaju et al., 2022). Household size distribution reveals that 56.4 % of the farmers had between 5–8 persons, 33.0 % had 1–4 persons, while 4.0 % had between 13–16 persons. The mean household size of 7 persons suggests that most households have sufficient family labor to support groundnut farming activities, reducing dependence on hired labor (Sarr & Camara, 2018). In terms of farm size, 40.7 % cultivated between 1.1–2.0 hectares, 29.3 % cultivated 0.1–1.0 hectares, and 16.2 % cultivated 2.1–3.0 hectares. The mean farm size of 1.9 hectares confirms that groundnut production in the area is largely small-scale. With respect to agricultural extension, 43.6 % of the farmers had 1–2 extension contacts, 37.3 % had 3–4 contacts, and 19.1 % had 5–6 contacts, with a mean of 4 contacts per season. The limited number of contacts reflects systemic challenges facing the Agricultural Development Programme (ADP), such as inadequate funding and poor extension agent-to-farmer ratios (Ezihe et al., 2019). Findings further indicate that 59.0 % of the farm-

Table 1: Socio-economic characteristics of groundnut farmers

Variable	Frequency	Percentage
Age		
20-30	88	25.1
31-40	91	26.0
41-50	165	47.0
51 & above	07	1.9
Mean	48	
Sex		
Male	150	42.7
Female	201	57.3
Marital status		
Single	132	37.6
Married	182	51.9
Divorced	16	4.6
Widow/widower	21	6.0
Level of education		
Primary	111	31.6
Secondary	133	37.9
Tertiary	19	5.4
Non-formal	88	25.1
Household size		
1-4	116	33.0
5-8	198	56.4
9-12	23	6.6
13-16	14	4.0
Mean	7	
Farm Size		
0.1-1.0	103	29.3
1.1-2.0	143	40.7
2.1-3.0	57	16.2
3.1 & above	48	13.7
Mean	1.9	
Extension contacts		
1-2	153	43.6
3-4	131	37.3
5-6	67	19.1
Mean	3.7	
Cooperative membership		
Yes	207	59.0
No	144	41.0
Participation in workshop		

1-2	112	31.9
3-4	178	50.7
5-6	61	17.4
Mean	3.7	
Farming Experience		
1-10	115	32.8
11-20	220	62.7
21-30	16	4.6
Mean	18	

Source: Field Survey data, 2024.

ers belonged to cooperative societies. Membership in cooperatives enables farmers to pool resources for input purchase, access credit, and benefit from shared information and innovations (Yasin et al., 2022).

Participation in agricultural training and workshops was relatively high, with 50.7 % attending 3–4 sessions, 31.9 % attending 1–2 sessions, and 17.4 % participating in 5–6 sessions. This implies that most groundnut farmers have access to basic training on improved farming practices. Finally, analysis of farming experience reveals that 62.7 % of the respondents had 1–10 years of experience, 32.8 % had 11–20 years, and 4.6 % had 21–30 years, with a mean of 18 years. This indicates that most of the farmers are well-experienced in groundnut cultivation and are familiar with the farming conditions of the area (Msowoya et al., 2016).

3.2 PERCEIVED IMPACTS OF CLIMATE CHANGE ON GROUNDNUT PRODUCTION

Table 2 presents the perceived impacts of climate change on groundnut farming in the study area. Among the estimated functional forms, the double-log model produced the most desirable results based on the number of significant variables and the high coefficient of multiple determination (R^2). The coefficient of multiple determination (R^2) value of 0.8641 indicates that approximately 86 % of the total variation in the dependent variable was explained by the independent variables included in the model. This suggests that the explanatory variables jointly provide a strong explanation of the variations in groundnut yield among the farmers. The F-value (11.140) was statistically significant, confirming the overall goodness-of-fit and the joint significance of the explanatory variables in the model. The results show that impact of poor and stunted growth was negative and statistically significant at the 1 % level. This implies that adverse climatic changes lead to poor vegetative development and reduced productivity of groundnut plants (Gershon & Mbajekwe, 2020). Extreme temperatures, erratic precipitation, and prolonged droughts create suboptimal growth conditions, constraining crop performance. The impact of pests and disease outbreaks were also negative and significant at the 1% level, indicating that temperature and rainfall extremes exacerbate pest and disease infestations in groundnut farms. As noted by Gairhe and Adhikari (2018), warmer conditions promote the proliferation of pests and pathogens, resulting in yield losses, inferior crop quality, and increased production costs. Similarly, impact of reduction in land yield was negative and significant at the 5 % level, suggesting that prolonged dry periods and other adverse climatic events diminish land productivity and overall yield (Dominic et al., 2017). Climate variability affects soil fertility, water availability, and growing conditions, thus constraining sustainable production. Impact of reduction in farm income was negative and significant at the 1% level, indicating that unfavorable temperature and rainfall patterns reduce both the quantity and quality of harvests. Consequently, groundnut farmers experience income losses arising from decreased yields, lower market prices, and higher production costs (Adriana et al., 2020). This negatively affects their livelihood and economic resilience. Impact of Increased rainfall intensity was negative and significant at the 1 % level. Heavy rainfall often leads to soil erosion, flooding, and nutrient leaching, which impair groundnut growth and yield (Abubakar et al., 2020). Excess moisture can also induce waterlogging, encourage fungal diseases, and reduce the availability of aerated soil conditions needed for optimal growth. Impact of prolonged dry seasons were negative and significant at the 1 % level, implying that water scarcity during critical growth stages hampers germination, flowering, and pod development, thereby reducing yield potential. Impacts of rising temperatures were likewise negative and significant at the 1 % level. Elevated temperatures disrupt photosynthesis and nutrient uptake, leading to heat

Table 2: Perceived impacts of climate change on groundnut production

Variable	Linear	Semi-log	Double-log	Exponential
Constant	-0.071	-4.315	-2.340	-5.809
	(-1.214)	(-3.408)***	(-2.772)**	(-2.822)**
Poor/stunted growth rate	-3.395	-4.505	-79.098	-0.723
	(-4.934)***	(-1.511)	(-4.777)***	(-1.105)
Pest and disease outbreaks	-22.133	-4.073	-4.790	-30.022
	(-2.502)**	(-0.051)	(-3.950)***	(-1.352)
Reduction in land yield	-15.414	-0.616	-14.205	-4.084
	(-1.113)	(-4.811)***	(-2.980)**	(-1.007)
Reduction in farm income	32.107	-0.194	--22.843	-0.501
	(0.049)	(-1.710)	(-4.100)***	(-3.921)***
Severe poverty	-10.251	-3.914	-29.169	-0.750
	(-4.410)***	(-0.121)	(-0.671)	(-2.402)**
Increased rainfall intensity	-62.103	-0.920	-0.719	-0.683
	(-1.033)	(-4.006)***	(-2.267)**	(-0.949)
Prolonged dry season	-0.673	-4.993	-0.677	-3.799
	(-2.901)**	(-0.878)	(-4.901)***	(-2.333)**
Frequent floods	-4.671	0.578	-12.743	-0.578
	(-1.098)	(1.278)	(-1.001)	(-0.901)
Increased temperature	-0.784	-31.788	-0.890	-5.901
	(-0.892)	(-2.688)**	(-3.671)***	(-1.038)
Severe windstorm	-0.788	-0.677	-0.990	-0.532
	(-2.541)**	(-1.790)	(-2.571)**	(-1.090)
Unpredictability of rainfall	6.800	-0.843	-0.878	-7.521
	(1.781)	(-3.454)***	(-3.801)***	(-1.011)
Late onset rain	-0.930	-1.780	-0.591	-0.680
	(-2.577)**	(-0.678)	(-1.441)	(-2.012)**
Early cessation of rain	-0.881	-4.432	-3.702	-0.990
	(-1.001)	(-0.601)	(-1.022)	(-3.001)***
R^2	0.6634	0.7651	0.8641	0.7821
F- ratio	22.209***	51.081	11.140	19.421***

Source: Field Survey data, 2024; Significant at ***1 %, and **5 %.

stress, poor pod filling, and greater susceptibility to pests and diseases (Abram et al., 2020). The impact of severe windstorms was negative and significant at the 5% level, indicating that strong winds can cause physical damage such as lodging, breakage, and defoliation of groundnut plants. These effects reduce yield quality and increase vulnerability to secondary infections (Onyeneke et al., 2022). Finally, impact of unpredictability of rainfall was negative and significant at the 1 % level. Irregular rainfall patterns hinder farmers' ability to plan planting and management activities effectively. As a result, planting schedules are disrupted, and synchronization with optimal environmental conditions becomes difficult, leading to poor growth and lower productivity (Onyemuwa et al., 2017). It is important to acknowledge that the purposive selection of Local Government Areas (LGAs) focused on regions with intensive groundnut production may constrain the generalizability of the study's findings to other areas of Ebonyi State, where groundnut cultivation is less prominent. However, this methodological choice enabled a more in-depth assessment of climate change impacts in high-production zones, which aligns with the study's objectives.

3.3 CLIMATE CHANGE ADAPTATION STRATEGIES ADOPTED BY GROUNDNUT FARMERS

Table 3 presents the adaptation strategies adopted by groundnut farmers in the study area. The results show that all the farmers (100 %) adopted the planting of improved groundnut varieties. This practice involves cultivating varieties developed to possess desirable agronomic traits such as higher yield potential, disease resistance, and tolerance to environmental stressors (Osuji et al., 2022b). Adoption of improved varieties enhances productivity and resilience against adverse climate fluctuations. Conversely, agricultural insurance recorded the least adoption rate (65.0 %). Insurance in this context refers to policies that provide coverage against yield loss, crop failure, or other climate-related risks. The low adoption level may be attributed to the high cost of insurance premiums and limited awareness among smallholder farmers. Intercropping or planting multiple crops was adopted by 85.8 % of the respondents. This practice mitigates climate-induced risks such as drought, flooding, or pest outbreaks by diversifying production systems (Osuji et al., 2022b). Similarly, 99.1 % of the farmers engaged in livelihood diversification by venturing into alternative income-generating activities outside groundnut farming. Such diversification strengthens household income stability and reduces vulnerability to climate shocks. Soil and water conservation practices were adopted by 85.2 % of the respondents. These include mulching, cover cropping, contour plowing, terracing, and the construction of drainage systems to minimize soil erosion and moisture loss (Tetteh et al., 2022). Moreover, 91.7 % of the farmers reported modifying their planting and harvesting schedules in response to shifting rainfall patterns, thereby aligning their operations with changing climatic conditions. Irrigation practices were employed by 87.2 % of the farmers as a supplementary water source during drought or erratic rainfall (Bekuma et al., 2022). Reliance on climate information and forecasts was also high (88.0 %), reflecting farmers' efforts to access and utilize meteorological data to inform planting, irrigation, and pest management decisions. Collaboration with agricultural extension workers was reported by 69.8 % of the farmers, underscoring the role of extension services in disseminating climate-resilient agricultural technologies (Yasin et al., 2022). Furthermore, 77.2 % of the farmers practiced appropriate fertilizer application to ensure balanced nutrient supply, while 74.1 % adopted efficient pesticide use through integrated pest management (Msowoya et al., 2016). Increased land access (67.2 %) and erosion control measures (88.9 %)—such as mulching, vetiver grass planting, and improved drainage systems—were also important adaptive strategies. Collectively, these measures demonstrate the farmers' proactive efforts to strengthen resilience against the adverse impacts of climate change. By combining agronomic adjustments, institutional support, and informed decision-making, groundnut farmers in Ebonyi State enhance their capacity to sustain production and livelihoods under changing climatic conditions (Simanjuntak et al., 2023).

3.4 FACTORS INFLUENCING FARMERS' ADAPTATION STRATEGIES

Table 4 presents the estimated results of the beta regression model showing the determinants of farmers' adaptation strategies to climate change. The coefficient of multiple determination (R^2) was 0.8708, indicating that approximately 87.1 % of the total variation in the adaptation behavior of farmers was explained by the explanatory variables included in the model. The F-statistic (190.0) was statistically significant, confirming that the model was well-fitted and that the explanatory variables jointly exerted a strong influence on farmers' adaptation strategies.

The age of farmers was negative and significant at the 1 % level, implying that the likelihood of adopting climate adaptation measures declines with increasing age. This result suggests that younger farmers are generally more open to innovation and risk-taking than older ones, who may rely more on traditional practices and exhibit lower flexibility in adopting new strategies (Ezihe et al., 2017). Education was positive and significant at the 1% level, showing that more educated farmers are better positioned to comprehend and respond to climate information. Education enhances awareness, decision-making, and access to information that facilitate climate-smart practices (Kadiyala et al., 2021). Household size had a positive and significant relationship with adaptation at the 5 % level. Larger households provide additional labor, shared knowledge, and pooled resources that enable more effective implementation of adaptive

Table 3: Adaptation strategies adopted by groundnut farmers to mitigate climate change

Adaptation strategies of groundnut farmers	*Frequency	Percentage
Planting improved groundnut varieties	351	100
Insurance	228	65.0
Planting of multiple/different crops	301	85.8
Livelihood diversification	348	99.1
Soil and water conservation techniques	299	85.2
Adjusting planting and harvesting dates	322	91.7
Irrigation	306	87.2
Reliance on climate information and forecasts	309	88.0
Collaboration with extension workers/agents	245	69.8
Appropriate application of fertilizer	271	77.2
Efficient and effective use of pesticide	260	74.1
Increased land access	236	67.2
Erosion control measures	312	88.9

Source: Field Survey data, 2024. *Multiple Responses

strategies. Access to capital was positive and significant at the 1 % level, emphasizing that financial resources are a major driver of adaptation. Farmers with adequate capital can afford improved technologies, irrigation systems, and climate-resilient inputs (Ajayi et al., 2020). Access to early climate change information was positive and significant at the 1 % level, reflecting that farmers who access early warnings and meteorological updates are more capable of making timely adjustments to mitigate adverse climatic impacts (Neelima et al., 2023). Participation in climate change training and workshops was positive and significant at the 5 % level, indicating that training, seminars, and extension forums enhance farmers' technical knowledge and adaptive capacity (Kemi et al., 2021).

Similarly, access to extension services were positive and significant at the 1 % level, suggesting that frequent interaction with agricultural extension personnel improves farmers' access to climate information, innovative technologies, and technical guidance (Obedgiu et al., 2024).

3.5 CONSTRAINTS ON ADOPTION OF CLIMATE CHANGE ADAPTATION STRATEGIES

The constraints affecting the adoption of climate change adaptation strategies among groundnut farmers are presented in Table 5. The results reveal that inadequate capital was identified by 99.7 % of the farmers as the major constraint influencing the adoption of climate adaptation measures. Insufficient financial resources limit farmers' ability to invest in the necessary technologies, tools, and inputs required for effective adaptation (Tabe-Ojong et al., 2023). Lack of capital also reduces their capacity to implement large-scale adaptation strategies, thereby weakening resilience to climate-related risks and shocks. A substantial proportion of the farmers (77.2 %) reported distant farmland as a hindrance to adaptation. Farmlands located far from farmers' residences pose accessibility challenges, constrain timely implementation of adaptation measures, and increase management costs, especially in areas with poor infrastructure (Mabhaudhi et al., 2018). Similarly, high cost and low availability of labour were reported by 90.8 % of the respondents as major barriers. Many climate adaptation practices are both capital- and labor-intensive, requiring significant manpower for implementation. In contexts where labour is scarce or costly, the adoption of these measures becomes increasingly difficult, especially among resource-constrained farmers. Technical difficulties in applying certain adaptation strategies were cited by 74.1 % of the farmers. This finding suggests that some farmers lack the technical know-how or training needed to implement complex adaptation practices effectively. Technical challenges, coupled with limited access to professional support, can discourage farmers from adopting innovative adaptation methods (Carr et al., 2022). Inadequate farmland was another constraint, reported by 97.4 % of the farmers. Limited land availability restricts the implementation of space-demanding adaptation practices such as crop diversification, contour farming, and soil conservation. Land fragmentation, reported by 94.9 % of the respondents, further compounds this issue. Fragmented land holdings make it difficult to coordinate

Table 4: Identified factors influencing farmers' adaptation strategies to climate change

Variables	Coefficients	t-values	S. E
Constant	7.2011	1.1091**	6.4927
Age	-9.4252	-6.0023***	1.5703
Education	0.9812	4.4210***	0.2219
Household size	0.9356	2.3051**	0.4059
Access to capital	34.4272	4.6041***	7.4775
Farming experience	-10.4219	-0.8001	13.0257
Farm size	-0.7803	-1.0052	0.7762
Seeking of early climate change information	5.3204	4.7535***	1.1192
Participation in climate change workshops	0.7095	2.4114**	0.2942
Experienced climate change eventualities	-7.2414	-1.0101	7.1689
Extension contacts	0.9009	5.1471***	0.1750
R^2	0.8708		
F-value	190.005		
N	351		

Source: Field Survey, 2024 ***Significant at 1 % ** Significant at 5 %

farm activities and hinder the adoption of large-scale or mechanized adaptation techniques (Ali et al., 2017). Poor extension access and services were identified by 82.0 % of the respondents. Extension agents play a critical role in providing information, technical guidance, and training on climate-smart agricultural practices. Limited access to these services reduces farmers' exposure to new knowledge and innovations essential for effective adaptation (Wei et al., 2022). Additionally, high cost of input materials such as improved seeds, fertilizers, pesticides, and irrigation equipment was reported by 100 % of the farmers, indicating that all respondents considered input costs a significant constraint. High input prices limit the scale of adoption and prevent many farmers from engaging in sustainable adaptation practices. Inadequate information on climate change was reported by 69.8 % of farmers, emphasizing the importance of timely and accurate dissemination of climate-related information. Without sufficient knowledge about climate trends, potential risks, and adaptive responses, farmers are less likely to take informed decisions (Olanrewaju et al., 2022). Lastly, lack of seriousness and poor attitudes towards climate change were identified by 57.3 % of the farmers. Some farmers exhibit skepticism about climate change impacts, which reduces their motivation to adopt proactive adaptation strategies (Tajudeen et al., 2022).

4 CONCLUSION

The findings of the study reveal that climate change has significantly impacted groundnut yield in Ebonyi State, Nigeria, through manifestations such as stunted crop growth, increased pest and disease outbreaks, declining land productivity, reduced farm income, heightened poverty levels, and intensified rainfall patterns. In response to these adverse effects, groundnut farmers have adopted various adaptation strategies including the cultivation of improved groundnut varieties, intercropping or planting of multiple crops, livelihood diversification, soil and water conservation techniques, adjustment of planting and harvesting schedules, and the use of irrigation practices. Empirical results further indicate that age, education, household size, access to capital, access to early climate change information, participation in climate change workshops, and access to extension services were significant determinants of farmers' adaptation strategies. Conversely, inadequate capital, distant farmlands, high labour costs and shortages, technical difficulties in applying adaptation practices, and limited farmland availability were identified as major constraints impeding the effective adoption of adaptation strategies. To enhance farmers' adaptive capacity to climate change, the study recommends the establishment of localized climate information centers and dissemination channels in rural farming communities. Furthermore, there is a need to organize continuous awareness and capacity-building campaigns on climate change and its implications for agricultural productivity. Finally, climate policy financing should be integrated into both national and state budgetary frameworks to support climate-resilient agricultural

Table 5: Constraints on adoption of climate change adaptation strategies

Constrained factors	*Frequency	Percentage
Inadequate capital	350	99.7
Distant farmlands	271	77.2
High cost and low availability of labor supply	319	90.8
Technical application of some adaptation strategies	260	74.1
Inadequate farming lands	342	97.4
Poor extension access and services	288	82.0
Land fragmentation	333	94.9
High cost of inputs materials	351	100
Inadequate information concerning climate change	245	69.8
Lack of seriousness and poor attitudes of farmers to climate change	201	57.3

Source: Field survey data, 2024. *Multiple responses

development and ensure sustainable groundnut production in the face of changing climatic conditions.

FUNDING

No funding received for the study

CONFLICT OF INTEREST

The authors declare that no conflict of interest exist

DATA AVAILABILTY

The study data are deposited in Alex Ekwueme Federal University, Nigeria official website at https://funai.edu.ng.

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