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Assessment of Climate Change Adaptation Strategies by Smallholder Farmers in Enugu State, Nigeria

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ABSTRACT: Climate change has emerged as a critical global challenge with far-reaching consequences, particularly for agricultural-dependent regions like Enugu State, Nigeria. This study aimed to explore the adaptation strategies employed by smallholder farmers in response to climate change. A mixed-methods approach, including perception surveys and analysis of meteorological data, was utilized to identify the convergence or divergence between local knowledge and empirical reality. The findings revealed a strong correlation between farmers' perceptions and scientific data, indicating that local communities' understanding of climate change is grounded in empirical evidence. The study showcased the proactive nature of smallholder farmers in the face of climatic uncertainties, with the adoption of diverse adaptation practices. The most prominent strategies included cultivating improved crop varieties with short gestation periods and diversifying portfolios through mixed farming and non-farm activities. While some capital-intensive strategies, such as terracing, irrigation, and drainage, were less prevalent, targeted support and policy measures are recommended to enhance their wider adoption. The interrelationship among various adaptation strategies underscores the multifaceted nature of farmers' response to climate challenges. In conclusion, this research offers compelling insights into the climate change adaptation practices of smallholder farmers in Enugu State. By aligning local knowledge with scientific evidence, the study provides a robust foundation for sustainable policy formulation and targeted interventions to bolster farmers' adaptive capacity and safeguard agricultural productivity and rural livelihoods in the region.

I. INTRODUCTION

Climate change stands as one of the most critical and pervasive threats faced by the world today. It encompasses statistical variations persisting for extended periods, such as shifts in the frequency and magnitude of sporadic weather events and a gradual rise in global average surface temperature [1]. The authors in [2] emphasize that climate change affects both average conditions and variability, leading to extreme events. Particularly vulnerable to climate change is agriculture, a vital component of human sustenance and a major contributor to the economy. The consequences of increased temperatures and shifting weather patterns are significant and enduring, negatively impacting agricultural output and the sustainability of farming regions. This, in turn, jeopardizes food supply and creates potential crises for populations in many developing countries.

The impacts of climate change have been felt globally, with the tropics experiencing profound effects [3]. These changes have triggered a multitude of physical and biological transformations worldwide, adversely affecting agriculture, human populations, and the environment [4]. It is worth noting that lower-middle and low-income countries, especially those in Africa, are more vulnerable to climate change impacts, yet readiness to improve resilience remains low in these regions [5]. Nigeria, for instance, ranks among the top ten most exposed countries to climate change, with approximately 6% of its land area estimated to be vulnerable to extreme weather events [6]. The consequences in Nigeria include rural-urban migration and reduced stream flow, among other documented impacts [7].

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In the southern areas of Nigeria, which are characterized by high rainfall, fluctuations in rainfall patterns have significantly affected vegetation. The savanna vegetation zone has been grappling with severe heatwaves. Similarly, the Sahel region faces the risk of losing approximately 30 hectares of cropland annually due to desertification [8]. Nigeria's water and wetland supplies have also been impacted by climate fluctuations, with many large water bodies experiencing reductions in flow rate and network length in response to decreased rainfall and higher evapotranspiration [9]. These changes have direct and indirect impacts on crop and animal productivity.

Crop production dominates Nigeria's agricultural sector, with some regions of the country already experiencing a 20% decline in the growing cycle [10]. Forest resources are also facing gradual extinction due to climate change impacts [11]. By 2050, the authors in [12] predict that crop harvests in Africa will be as low as 50% due to climate change, resulting in increased risk of low output, crop loss, and livestock mortality. The soaring temperatures have significantly affected animal productivity, especially in poultry, swine, cattle, sheep, and goats. Reports indicate that farmers in Enugu state have experienced reduced cattle procreation and increased livestock deaths, leading to some giving up on cattle rearing altogether [13].

Environmental destruction, biodiversity loss, and dwindling water supplies have negative implications for food security, particularly in developing countries like Nigeria [14]. The direct impacts of climate change on agriculture in developing countries primarily manifest in output and income loss, further exacerbating challenges related to poverty and hunger [15].

Enugu state, heavily reliant on agriculture for survival, has become increasingly vulnerable to climate change impacts on its agricultural sector. Evaluating the extent of climate change's effects on agriculture in Enugu state and understanding farmers' adaptation strategies is crucial. This information can inform the development of a robust institutional framework by governmental and non-governmental organizations to support farmers and mitigate the negative impacts of climate change on agriculture and the economy at large.

II. REVIEW OF RELATED LITERATURE

A study conducted by Abugu, Yero, Odele, and Amahagbor [16] titled "Reviewing the links between climate change and resource conflict" sought to establish the intricate connection between climate change and conflicts in Nigeria, particularly focusing on conflicts between farmers and herders. Employing a literature review methodology, the researchers carefully examined existing literature that links climate change and resource conflict to identify any missing links. The review encompassed literature published from the late 1990s to 2021, with the selection of papers based on the relevance of the topic and date of publication. The results showed a general consensus among scholars that climate change indeed influences resource conflicts. However, some authors emphasized that climate change does not directly cause resource conflicts in isolation but rather exerts its impact through influencing other factors that affect resource availability, accessibility, and utility. As a result, the authors concluded that resource conflicts may be considered secondary or tertiary effects of climate change.

In a study by Durodola [17] titled "The Impact of climate change-induced extreme events on agriculture and food security: a review on Nigeria Agricultural sciences," the author focused on the effects of extreme events, such as floods and droughts, caused by climate change on agriculture and food security, with a specific focus on Nigeria. The study employed a review of literature, utilizing both electronic and non-electronic databases to identify research conducted on the effects of climate change and extreme events on agricultural productivity. The author's analysis revealed that extreme events, particularly droughts and floods, have significant impacts on agriculture and food security in Nigeria.

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Audu et al. [18] conducted a study in Abuja, Nigeria, titled "Climate change and its implication on Agriculture in Nigeria." The study focused on the relationship between climate change and agricultural activities in the country. Employing a literature review and secondary data analysis with inferential statistics, the authors calculated the mean decadal temperature for six meteorological stations and analyzed occurrences and length of dry spells for 30 years (1981-2010). The study revealed various implications of climate change on agriculture, including changes in rainfall characteristics, erosion/floods, and increased incidence of pests and diseases.

Apatat [19] aimed to present an empirical analysis of the effects of global warming on Nigerian agriculture and estimate the determinants of adaptation to climate change. The study utilized data from both secondary and primary sources and analyzed determinants of farm-level climate adaptation measures using a Multinomial choice and stochastic-simulation model. The investigation revealed that hunger-related deaths could increase if grain productions do not keep pace with population growth in an unfavorable climatic environment.

Ifeanyi-Obi et al. [20] conducted a study titled "Challenges faced by cocoyam farmers in adapting to climate change in Southeast Nigeria." The study examined the challenges faced by cocoyam farmers in adapting to climate change in the region. Employing a multi-stage sampling technique, the researchers collected data using structured questionnaires and interviews from 384 respondents. The study identified several major challenges faced by cocoyam farmers in adapting to climate change, including lack/high cost of farm inputs and low soil fertility, land and labor constraints, poor access to information and ineffectiveness of cooperatives, lack of/poor access to fund and credit facilities, lack of improved varieties of cocoyam, poor value attached to cocoyam, poor infrastructural capacity and technology know-how, and transportation constraints.

These studies collectively shed light on the significant impacts of climate change on agriculture and resource conflicts in Nigeria. They underscore the need for robust adaptation measures and strategic interventions to mitigate the adverse effects of climate change on the country's economy and livelihoods.

III. METHODOLOGY

3.1 Area of Study

Enugu State, situated in South-east Nigeria is characterized by a tropical rainforest zone with a derived savannah. The city of Enugu experiences a tropical savanna climate, with a notable level of humidity throughout the year, peaking between March and November. The mean daily temperature for the entire state is recorded at 26.7 °C [2]. The region receives an average annual rainfall of approximately 2,000 millimeters (79 inches), with intermittent showers that intensify during the rainy season. The weather also includes the occurrence of Harmattan, a dusty trade wind that prevails for a few weeks during December and January [13]. The population of Enugu State stands at 3,267,837, according to the National Population Commission's data from 2006. The state is further subdivided into three senatorial zones and seventeen (17) local government areas.

Agriculture plays a crucial role in Enugu State's economy, with the production of various crops such as yam, cassava, rice, maize, pineapple, banana, and palm, among others. The residents are actively engaged in poultry production and small livestock rearing, particularly sheep and goat farming, among other agricultural activities. These agricultural practices are vital to the state's economy and contribute significantly to the livelihoods of the people in the region.

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3.2 Sampling Techniques

In this study, a sample size of 400 farmers was determined using the Yamane Taro method to ensure adequate representation and meaningful insights. The researchers adopted a multistage sampling approach to ensure fair and comprehensive selection of respondents across Enugu State.

The first stage involved the division of Enugu State into three senatorial zones: Enugu North (Nsukka), Enugu East (Nkanu - Awgu), and Enugu West (Udi – Oji River) Senatorial districts. From each of these zones, two local government areas were carefully chosen based on the occurrence of climate change disasters from 2001 to 2021. The selected local government areas were Uzo Uwani and Nsukka (Enugu North), Nkanu East and Isi-Uzo (Enugu East), and Awgu and Aninri (Enugu West).

In total, six (6) local government areas were opportunistically sampled in the first stage. For the second stage, the researchers utilized simple random sampling to select five communities from each of the six (6) local governments, leading to a total of 30 communities.

The final stage involved the selection of 13 farmers from each of 29 out of the 30 communities using the snowball sampling technique, resulting in a total of 377 farmers. However, in the last community, which is Adani in Uzo-Uwani L.G.A, a total of 23 farmers were selected. This decision was made due to Adani's significance as a former farm settlement and the current location of Ada Rice, one of the most prominent rice farms in Nigeria.

In this manner, the researchers were able to achieve a total sample size of 400 farmers for the study, ensuring comprehensive coverage and representation across the state. This robust sampling approach enhances the reliability and validity of the study's findings, providing valuable insights into climate change adaptation strategies of smallholders in Enugu state.

3.3 Method of Data Analysis

Multivariate Probit Model (MVP)

In this study, the researchers employed the multivariate probit technique to examine the interdependence of various adaptation practices and the socioeconomic factors that influence farmers' decisions regarding these practices. The adaptation practices were represented as nominal variables, and the researchers transformed them into dichotomous dependent variables to capture whether a specific practice was adopted by a farmer or not. For each adaptation practice, a binary dependent variable was constructed. If a farmer adopted a particular practice, it was coded as 1, and if not, it was coded as 0, adhering to the principles of binary coding [21]. This resulted in a set of eight binary dependent variables ($Y_1 \ldots \ldots Y_8$) representing the different adaptation choices made by farmers, such that:

$$Y_i = 1 \; if \; \beta i X' + \varepsilon i > 0 \qquad (3.1)$$

$$Y_i = 0 \; if \; \beta i X' + \varepsilon i \leq 0, i = 1, 2, \ldots, 8 \qquad (3.2)$$

where

i = 1,2, … ,8 are the chosen climate risk management practices/adaptation options; X represents the vector of the predictors (independent variables); βi is the parameter estimates of the predictors; and εi, random error vectors having a zero mean, unitary standard deviation, and an 8×8 correlation matrix. Equations 3.3 and 3.4 represent the multivariate probit framework of this study. The multivariate probit (MVP) approach was chosen as the modeling framework for analyzing the factors influencing farmers' adaptation decisions. The MVP framework offers several advantages, one of which is its ability to handle simultaneous or sequential decisions that farmers make in managing climate risks. Farmers often make decisions that complement or substitute each other when choosing climate risk

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management strategies, and the multivariate probit model allows for the interpretation of such simultaneous adaptation decisions. This is particularly useful as it helps to understand how various adaptation practices are interrelated and how they can jointly contribute to climate risk management.

In summary, the multivariate probit framework used in this study allowed the researchers to comprehensively analyze the relationships between different adaptation practices and the socioeconomic factors affecting farmers' decisions, offering valuable insights into climate risk management strategies in the agricultural context.

IV. RESULT AND DISCUSSION

Table 4.1: Distribution of farmers according to climate change adaptation strategies adopted (n =400)

Adaptation Strategy	Frequency	Percentage
1. Use of improved varieties		
Use of short gestation crops	292	73
Use of flood tolerant crop	208	58
Use of drought tolerant crops	224	56
Use of disease/pest resistant varieties	208	58
Planting different varieties of crops	380	95
2. Portfolio diversification		
Diversifying from farm to non-farm activities	272	68
Changing from crop farming to livestock farming	264	66
Mixed farming	272	68
3. Soil and water conservation		
Terracing	192	48
Mulching	280	70
Planting of cover crops	280	70
Crop rotation	280	70
Water harvesting	272	68
4. Changing planting dates		
Adjusting planting dates	313	78
Shortening the length of growing period	304	76
5. Changing tillage operations		
Planting on mounds and planting on ridges	313	78
6. Planting Trees		
Planting Trees	313	78
7. Irrigation and drainage		
Irrigation/watering	172	43
Drainage	196	49
8. Farmland management		
Changing land area cultivated	313	78

Source: Field survey conducted by the researchers.

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The various climate change adaptation measures farmers adopt were classified into eight broad categories as shown in Table 4.9 and they include cultivating improved crop varieties, portfolio diversification, practicing soil and water conservation, adjusting time of sowing, changing tillage operations, planting trees, irrigation, and farmland management. These are considered important climate change adaptation strategies in Nigeria. Crop diversification – cultivating different crops – was adopted by majority of the farmers (95%). The dominant practice under crop diversification is intercropping of cassava, maize, groundnut and melon. This option is not expensive to practice and farmers have various crops at their disposal to plant. This may be the reason for greater adoption of this option. The increasing unpredictable nature of Enugu states's climate predisposes farmers to risk and shock associated with climate change, hence, makes them to grow different crop varieties. Planting short gestation crop varieties was also commonly practiced by farmers (73%) in the area.

Mixed farming was the commonly used (68%) practice under portfolio diversification by the farmers followed by diversifying from farm to non-farm livelihood activities. Mixed farming is not new to farmers in the area. Farmers who *ab initio* combined livestock production and crop production are gradually intensifying on crop production only because of increasing scarcity of fodder for livestock like cattle, sheep and goat. Farmers in the area whose animals are affected seriously by climate change are resorting to only crop production. Another related practice is farmland management which 78% of the farmers adopted.

The commonly practiced conservation strategies were crop rotation, cover cropping and mulching. Mulching was practiced due to its benefit in soil moisture conservation and soil fertility management which often increases farmers' yield. The reasons for embarking on cover cropping lies in the fact that cover crops suppress weeds, conserve soil moisture, and add nutrient to the soil. Crop rotation is also a common adaptation strategy by farmers in the area and the probable reason for its adoption by about 70% of the farmers is because it enhances production, controls pest and diseases, conserves soil moisture and is less expensive.

Furthermore, about 79% of the farming households reported that because of the erratic rainfall pattern in the area, they now change the time of planting to match the current distribution and pattern of rainfall. Also, 76% of the farmers reported that the growing periods have been shortened. Changing tillage operations was another common (78%) practice because of its characteristic benefit of controlling farm erosion and soil moisture conservation. Also, 70.00% of the farmers opted for planting trees on farms to serve as shade and help in protecting crops from scorching and controlling farm erosion. Farmers also opted for this strategy because it contributes to mitigation of carbon and increases their income through sales of the products of the trees planted.

Terracing (48%) was not common in the area and may be as a result of constraining factors such as high labour requirement, frequent inspection, large expanse of farmland needed, and the huge construction material required. Also, irrigation (43%) and drainage (49%) were not commonly practiced by the farmers, perhaps because these options are capital intensive.

The researchers classified the adaptation options into eight broad categories. For categories having more than one specific adaptation option, the authors summed such adaptation options and divided by the number of specific adaptation practices identified/mentioned under such category as presented in Table 4.9. The quotient was further converted to percentage by multiplying by 100 and any farmer with a percentage score of 50 and above was considered as an adopter of such category while those with a percentage score of less than 50 were considered as non-adopters. These categories were used as the dependent variables in the multivariate probit model of this study presented in table 4.2.

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Adaptation Category	Improved varieties	Portfolio diversification	Soil and water conservation	Changing planting dates	Changing tillage operations	Planting trees	Irrigation and drainage	Farmland management
Improved varieties	1.000							
Portfolio diversification	0.346**	1.000						
Soil and water conservation	0.428**	0.343**	1.000					
Changing planting dates	0.606**	0.431**	0.632**	1.000				
Changing tillage operations	0.06	0.092	0.210**	-0.071	1.000			
Planting trees	0.424**	0.310**	0.677**	0.688**	0.127	1.000		
Irrigation and drainage	0.475**	0.475**	0.465**	0.376**	0.281**	0.467**	1.000	
Farmland management	0.427**	0.522**	0.654**	0.650**	0.021	0.577**	0.356**	1.000

Table 4.2: Correlation coefficients of the adaptation categories (from the MVP) (n=400)

**p < 0.01

The multivariate probit model results on the factors determining choices of adaptation options are presented in Tables 4.10. The model is very fit considering the significance of the likelihood ratio result ($Chi^2 = 202.68$, $p < 0.01$). This led to the rejection of the hypothesis of independence of the random errors of the different adaptation models and acceptance of the alternative hypothesis of interdependence of the adaptation practices.

V. CONCLUSION

The present study is a comprehensive investigation that bridges the gap between farmers' perceptions of climate change and the use of indigenous knowledge system in developing adaptation strategies.

One of the notable outcomes of this study is the proactive response of smallholder farmers to the observed vagaries in climate. These resilient farmers have astutely adopted a range of climate change adaptation strategies, demonstrating their awareness of the detrimental impacts of climate change on crop production capacity and economic returns. Among the most prominent adaptation practices observed were the cultivation of improved crop varieties, especially those with short gestation periods, as well as the adoption of portfolio diversification through mixed farming and non-farm livelihood activities.

Furthermore, the study highlighted the crucial role of soil and water conservation practices in enhancing farmers' resilience to climate change. Practices such as crop rotation, mulching, cover cropping, and water harvesting were frequently employed by farming households, illustrating their understanding of the importance of sustaining soil moisture and fertility to achieve higher yields in the face of changing climate conditions.

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In response to the erratic rainfall patterns experienced in the area, farmers demonstrated adaptive flexibility by adjusting their planting dates, a strategy embraced by a significant portion of farming households. Additionally, the adoption of changing tillage operations was a common practice to mitigate farm erosion and conserve soil moisture, reinforcing the notion that farmers are actively seeking ways to safeguard their agricultural endeavors against climatic uncertainties.

Moreover, the study revealed that planting trees on farms was another valuable adaptation strategy utilized by farmers to provide shade, protect crops from scorching temperatures, and contribute to carbon mitigation. The income generated from the sale of tree products further incentivized the adoption of this practice, demonstrating the interconnectedness of climate change adaptation and livelihood enhancement.

Although some capital-intensive adaptation options, such as terracing, irrigation, and drainage, were less commonly practiced, this finding underscores the potential significance of targeted support and policy measures to enable wider adoption of such strategies and enhance farmers' climate resilience.

In conclusion, this study emphasizes the validity of farmers' perceptions in capturing empirical reality and their active engagement in adopting climate change adaptation practices. The interrelationship among various adaptation strategies underscores the holistic and multifaceted nature of farmers' response to climate challenges. As climate change continues to pose significant threats to agriculture and livelihoods in Enugu State, the findings of this study offer critical insights to policymakers, agricultural extension services, and development organizations, enabling the design and implementation of targeted interventions that support and strengthen farmers' adaptive capacity in the face of evolving climatic conditions. By embracing a data-driven approach that bridges local knowledge and scientific evidence, this research provides a compelling foundation for sustainable climate change adaptation planning and policy formulation to safeguard agricultural productivity and rural well-being in the region.

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