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Effect of Climate Change Adaptation Measures and the Vulnerability Index of Smallholder Rice Farmers in North Central Nigeria

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ABSTRACT

The study assessed the effect of climate change adaptation measures on the vulnerability index of smallholder rice farmers in North-Central Nigeria. Specifically, it determined the vulnerability index of smallholder rice farmers and examined the relationship between climate change adaptation measures and the vulnerability index. Primary data were collected using structured questionnaires from a population of 1,440 rice farmers, while a multi-stage and purposive sampling technique was employed to select 322 farmers in the study area. Descriptive statistics, the livelihood vulnerability index, Principal Component Analysis (PCA), and Correspondence Analysis (CA) were used to quantify the data, while the Pearson correlation coefficient was applied as an analytical technique.

The findings revealed a vulnerability index of -0.0032, indicating a negative and high level of vulnerability among smallholder rice farmers in the study area. This can be attributed to incessant flooding, excessive rainfall, and unpredictable levels of weather faced by farmers in the North central region of the country, coupled with inadequate resources to adopt climatic adaptation measures among smallholder rice farmers. Regarding the effect of climate change adaptation measures, the results showed significant and positive effects among adopters of certain measures, including crop diversification (1%), pesticide and fertilizer adjustment (5%), increased water conservation (5%), diversification of farm activities (1%), multiple planting dates (10%), watershed management (10%), and drought- and pest-tolerant cultivars (1%). The negative coefficient for non-adopters suggests that households not adopting such measures are more likely to experience adverse effects from climatic events such as droughts, floods, or extreme weather.

It was therefore recommended that smallholder rice farmers be trained on climate-smart agricultural (CSA) practices. Additionally, agricultural insurance should be promoted and made readily available to enable farmers to access funds and insure their farms against climate risks.

Keywords: Climate Change, Adaptation Measures, Vulnerability index, Smallholder Rice Farmers, North Central Nigeria.

1. INTRODUCTION

1.0 Background of the Study

Agriculture plays a vital role in the national gross domestic product (GDP), foreign exchange earnings, and food security of nations worldwide. However, despite these efforts, many obstacles remain facing agricultural businesses worldwide, particularly in sub-Saharan Africa (Food and Agricultural Organization (FAO) 2019). Most prominent among these are elements linked to climate change, such as variations in rainfall patterns, increasing temperatures, an increase in the frequency of droughts, and declining soil fertility (Stephen, 2015). Hence, ensuring food and nutrition security in rural communities that are highly vulnerable to climatic variability have become increasingly complex. Importantly, the recent argument on climate change has led to reawaken attention on climate change effects on agriculture. Increasing temperatures (a sudden hot spell or cold snap) and variations in rainfall patterns (a lengthy period of insufficient or excessive rainfall) impact negatively on agricultural yields of both rain-fed and irrigated crops (Gommes*et al.* 2019). These effects are manifested through crop yields, water availability, pests and disease, animal health and other biophysical factors (Jalloh *et al.,* 2015). However, for centuries rural farmers in Sub-Sahara Africa have evolved various survival strategies to combat the adverse effects of climate variability on crop production. Some of these schemes are multiple cropping systems, cropping drought resistant or drought tolerant crops and diversification of livelihood activities (Smith, 2022).

Climate change is predicted to bring about further changes in infrastructure necessities, costs, and agricultural productivity, which might ultimately limit the quantity and quality of food produced (Felix, 2019). According to Food and Agricultural Organization (FAO) 2015, more than $100 billion USD was expended worldwide in 2015 on the risks and expenses associated with climate change's effects on agricultural productivity, including crop and animal losses from droughts and flooding. Other empirical studies (Adebayo *et al.,* 2011 and, Godwin, 2015) showed that, despite the losses that have been documented, there will likely be more extreme weather events in the future, including storms, droughts, variations in precipitation, and temperature swings making smallholder farmers more vulnerable to climate change particularly in Nigeria.

1.1 Statement of the Problem

Despite numerous initiatives by successive Nigerian administrations to advance the agricultural sector, evidence indicates that smallholder farmers who make up the bulk of the nation's food producers remain highly susceptible to the impacts of climate variability. According to Climate Action Digest (2020), Nigeria is the 55th most vulnerable country to climate change and 22nd least ready. Since the bulk of food production in the country is carried out by these smallholder farmers with high vulnerability to climate risk, the volume of food production in the country is greatly threatened. According to Climate Action Digest (2020), smallholder farmers' vulnerability due to climate change is projected to cost 6%-30% of Nigeria's Gross Domestic Product (GDP) by 2050, translating to $100billion-$460billion in losses.

According to global climate litigation report of (2020) by United Nations Environment Programme (UNEP) asserted that, the future impact of climate change will far outstrip the devastation effects of the global coronavirus of 2019 (Covid 19). This review further confirmed that of Kuta (2011) who asserted that climate change is one of the most critical challenges ever to face humanity. It can cause the worst forms of economic and security problems for humanity (economic, social and food insecurity). It determines the health of the resources on which the economy depends and this phenomenon is one of the challenges confronting West Africa (Nigeria) among other sub-regions of the world. In designing a climate change adaptation policy that will enhance the food security status and reduce the vulnerability of smallholder farmers to climate change, it is crucial to examine various issues associated with the existing adaptation measures of these farm households to climate change.

Studies (Mohammed *et al*., 2022; Chukwuemeka *et al*., 2018; Eze*et al*., 2018; Ayinde*et al*., 2018; and Adeoti*et al*., 2016) have been conducted by various researchers in Nigeria, suggesting how vulnerability to climate change among smallholder farmers can be reduced. None of these studies looked at the effectiveness of climate change adaptation measures of smallholder farmers in the North Central considering the significant of the region in terms of food security in Nigeria.

Thus, this study examined the effects of climate change adaptation measures on vulnerability index of smallholder rice farmers, as well as the relationship existing between climate change and Vulnerability index of smallholder's rice farmers in the North central Nigeria. The specific objectives were to;

1. determined the vulnerability index of smallholder rice farmers to climate change in the study area, and
2. examined the relationship between climate change adaptation measures and vulnerability index of smallholder rice farmers?

2.0 Review of Related Empirical studies

In a study an assessment of rice farming households' vulnerability to climate change in Kwara State, Nigeria by Sheu-Usman *et al*. (2018) observed a vulnerability assessment index of 0.3001 a measure of the exposure, susceptibility and resilience/capacities of rice farmers) indicating that the study area is prone to the adverse effect of climate; this could be adduced to the problem of constant flooding occasioned by proximity to the river Niger. The high value has a negative effect on their livelihood as their livelihood is threatened. The high value might be because they are highly exposed and susceptible to climatic induced hazards coupled with low adaptive capacity.

Similarly, Adeboye*et al.* (2012) on Farmers' Awareness, Vulnerability and Adaptation to climate Change in Adamawa State, Nigeria opined that high and extreme temperature causes wilting of crops and diseases while excessive rainfall leads to destruction of farmlands and properties by flooding leaving farmers more vulnerable to the effects of climate change.

Adtedor (2015) examined Agricultural Vulnerability to Climate Change in Sokoto State, Nigeria**.** Monthly rainfall, rain days and temperatures (minimum and maximum) data for Sokoto (1951-2010) were sourced from the archives of the Nigerian Meteorological Agency, Lagos. It was observed that, while there were downward trends of annual rainfall and rain days in Sokoto, annual mean temperatures show upward trend.

In addition, annual droughts were of slight and moderate intensities during the period under review. The results also revealed that unreliable rainfall, desertification, increasing temperatures, scarcity of pastures and inaccessibility to credit facilities accounted for 86% of the variation of agricultural vulnerability to climate change in the selected settlements in Sokoto State.

Idoma*et al.* (2017) studied farmer's adaptation strategies to the effect of climate variation on rice production in Agatu Local Government Area of Benue State. Multi-stage sampling technique was used to select two hundred and forty respondents for the study. The result of Pearson product moment correlation indicated that there were significant and positive relationships between perceptions of climate change indicators (increasing flood, increasing hot temperature, unpredictable rain and shorter duration of rain) and adaptation strategies.

3.0 METHODOLOGY

3.1 Study Design

The study adopted the survey design approach, which involves observing events once from a single observation of a sample (Iheanacho and Iheanacho, 2012). The study's is correlational because it involved gathering data from various farmers in the study area over a brief period of time Iheanacho and Iheanacho (2012), (Thomas 2020), and examining the various associations between dependent and independent variables.

3.2 The Study Area

The study was conducted in North Central Nigeria. The North central Zone is made up of six states (Benue, Kogi, Kwara, Nasarawa, Niger and Plateau) and the Federal Capital Territory (FCT), Abuja. While the states have 114 Local Government Areas with a total population of over 20million (National Population Census 2006), the FCT has 6 council areas with a population of about 1.41 million. The zone is agrarian as the main employer of labour is agriculture with few commercial centers in form of modern and local markets. Crops produced in the zone include yam, rice, sorghum, maize, acha, benniseed, fruits, vegetables, etc. Every state in the zone is endowed with abundant solid minerals. The North Central stretches across the whole width of the country, from the border with Cameroon to that with Benin. In terms of the environment, the zone is dominated by the Guinean forest–savanna mosaic, with the western portion falling into the West Sudan Ian savannaEco region. The North Central region lies between latitudes 7°00′ and 11°30′ North of the Equator and longitudes 4°00′ and 11°00′ East of the Greenwich Meridian. It enjoys the tropical continental climate characterized by wet and dry seasons. The vegetation of the North Central Nigeria cut across the three savannah belts (Guinea, Sudan and Sahel) and this is one of the reasons why both roots and cereals cropping are very popular in these ecological zones (Sahel Savanna in Nigeria 2022).

3.3 Population of the Study/ Sample Size/ and Sampling Technique

The population of the study consisted of 1440 registered small-scales rice farmers in Guma LGA, Awe LGA, and Ankpa LGA from Benue, Nasarawa, and Kogi States respectively (Benue Agricultural and Rural Development Authority (BNARDA) 2022, International Fund for Agricultural Development (IFAD) 2023, Agricultural Divisional Office (ADO) 2023. The sample size for the study was 322 small scale rice farmers. Bow Ley's proportional allocation formula was used to ensure fair representative of the respondents from the stratum (State), Multi stage sampling techniques was applied in this study.

3.4 Model Specification

The livelihood vulnerability index was specified as follows:

Vulnerability = (adaptive capacity) – (sensitivity + exposure)

$HVI = (W_1A_1 + W_2A_2 \ldots W_nA_n) – [(W_1S_1+W_2S_2\ldots W_nS_n) + (W_1E_1+W_2E_2\ldots W_nE_n)]$ ------(4)

Where:

HVI = household vulnerability index

W_1-W_n = weights obtained from first principal component scores

A_1-A_n = adaptive variables (access to loan, livelihood diversification, formal education, application of manure, use of improved varieties, agroforestry practices)

S_1-S_n = sensitivity variables (crop failure due to increasing flood, crop failure due to drought, reduction in crop yield)

E_1-E_n = exposure variables (experiencing flooding, drought, and erosion)

3.5 Data Analysis Techniques.

Inferential statistics was used to analyze the data. Livelihood vulnerability index was used to determine the vulnerability of farmers to climate change. Principal Component Analysis (PCA) and Correspondence Analysis (CA) were used to quantify data and the result of both PCA and CA was used to compute the vulnerability index.

4.0Results and Discussion

4.1 Vulnerability Index of Rice Farmers

Table 1 shows the vulnerability index of smallholder rice farmers in the study area. The parameters used to measure the vulnerability index of the smallholder rice farmers were rice farmers' level of exposure, sensitivity, and adaptive capacity. The vulnerability index is measured based on the work of Sheu-Usman (2018), who opined that when the mean score of a farmer's adaptive capacity is less than one (1) it is considered vulnerable to climate change.

The result indicated that the mean score of rice farmers' adaptive level to climate change is -0.0032; this shows a negative and high level of vulnerability. This can be attributed to incessant flooding, excessive rainfall, and unpredictable levels of weather faced by farmers in the study area, coupled with inadequate resources to adopt climatic adaptation measures. This is in line with the report of Adeboye*et al.,* (2012), who opined that high and extreme temperatures cause wilting of crops and diseases, while excessive rainfall leads to destruction of farmlands and properties by flooding, leaving farmers more vulnerable to the effects of climate change. Also, Onyeneke*et al.,* (2017), noted that smallholder rice farmers in Nigeria who failed to adopt climate-smart practices, such as alternate wetting and drying techniques or crop rotation, exhibited lower resilience to climatic variability.

Table 1 Rice Farmer's Vulnerability Index

Household Vulnerability index	Benue	Kogi	Nasarawa	Pooled (N.C)
Mean	-0.1890	0.4114	-0.1214	-0.0032
Std deviation	1.39	1.45	2.37	1.75
Minimum	-3.43	-3.18	-16.37	-16.37
Maximum	1.84	1.84	1.84	1.84

Source: Field Survey data 2024

4.2 Effect of Climate Change Adaptation Measures on Vulnerability Index of Rice Farmers

Table 2 shows the effects of climate change adaptation measures on household vulnerability in the study area. The result shows significant effects between the adopters of some climatic measures such as crop diversification was significant at (1%), pesticides and fertilizer adjustment (5%), increase in water conservation (5%), diversification of farm activities (1%), multiple planting dates (10%), water shade management (10%), drought and pest-tolerant cultivars (1%) level. The non-adopters of such measures having a negative coefficient suggest that non-adopting households are more likely to experience adverse effects (outcomes) in the face of climatic events such as droughts, floods, or extreme weather. This implies that their lack of adaptation measures (e.g., drought-resistant crops, water management systems, or diversification of farm activities) leaves them exposed to greater risks, thus increasing their vulnerability compared to adopters. This finding is in support of the findings of Idoma*et al. (2017)* who opined that there is a significant and positive relationship between perception of climate change indicators (increasing floods, increasing hot temperatures, unpredictable rain) and adaptation strategies.

This reveal also implies that the null hypothesis, which states that there is no significant relationship between adaptation measures and vulnerability index of smallholder rice farmers in the study area, is therefore rejected. The significant and positive coefficient suggests that households employing climatic measures have greater adaptive capacity to withstand the negative effect of climate change**.** This adaptive capacity translates into a reduction in overall vulnerability index, as smallholder rice farmers can continue to produce under changing climatic conditions.

Table 2 Effect of Climate Change Adaptation Measures on Vulnerability Index of Smallholder Rice Farmers

Variables (Vulnerability Index)	Mean score	Mean difference	t-value	p-value
Crop Diversification				
Adopters	-0.007	-0.00955	-0.048	0.000***
Non adopters	0.0021			
Pesticide and fertilizer Adjustment				
Adopters	0.1532	0.51183	2.258	0.025**
Non adopter	-0.3586			
Increase Water Conservation				
Adopters	0.2329	0.49741	2.0381	0.018**
Non-Adopters	-0.2645			
Divarication of Farm Activities				
Adopters	0.6268	1.66012	8.486	0.000***
Non-Adopters	-1.0333			
Smart Farming Techniques				
Adopters	-0.0626	-0.14998	-0.762	0.447 ^{NS}
Non-Adopters	0.0874			

Variables (Vulnerability Index)	Mean score	Mean difference	t-value	p-value
Multiple Planting Dates				
Adopters	0.6310	0.84524	3.757	0.000***
Non-Adopters	-0.2142			
Seeking Early Earning Information				
Adopters	0.2342	0.38583	1.793	0.074*
Non-Adopters	-0.1517			
Water shade Management				
Adopters	0.2438	0.38234	1.805	0.072*
Non-Adopters	-0.1385			
Climate Resilient Rice Varieties				
Adopters	0.0514	0.03394	0.157	0.876 NS
Non-Adopters	0.0174			
Drought & Pest Tolerance Cultivars				
Adopters	0.3733	0.65746	3.155	0.002***
Non-Adopters	-0.2845			
Weather Insurance				
Adopters	0.0694	0.05803	0.236	814 NS
Non-Adopters	0.0114			
Use of Irrigation Farming				
Adopters	0.0668	0.05435	0.227	0.821 NS
Non-Adopters	0.0124			

Source: Field survey dada, 2024 * = sig@1%, ** = sig@5%, * = sig@10%, NS = Not significance**

4.3 Conclusion and Recommendations

Evidence from the study has shown that smallholder farmers who adopt climate change adaptation measures such as crop diversification, pesticide and fertilizer adjustment, increased water conservation, diversification of farm activities, multiple planting dates, watershed management, and drought- and pest-tolerant cultivars, at the p-value levels of 0.01 and 0.05, build more adaptive capacity to withstand climatic shocks and vulnerabilities, thereby becoming undoubtedly more food secure in the North Central Nigeria. It can also be deduced that smallholder farmers in Benue State are the most affected and vulnerable to climate change in the study area, with a vulnerability index of -0.1890. This indicates that smallholder rice farmers show limited sensitivity to the terrain of the State, thereby making them more exposed to climate-related shocks than their counterparts.

The following recommendations are made based on the findings of the study:

i. A comprehensive approach by all the stakeholders (government, non-governmental organizations, and research institutes) in developing and localizing national climate adaptation policiesthat aligned with international agreements to help rural farmers adopt and build adaptive capacity.

ii. Integration of climate resilience practices into urban planning, agriculture, and infrastructure development to build the capacity of local farmers to adapt to climate change and overcome vulnerabilities

iii. Breeding of crops varieties that are more tolerant to climatic shocks, pest and diseases should be encouraged.

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