CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Faculty of Tropical AgriSciences

ASSESSMENT OF CLIMATE CHANGE ADAPTATION STRATEGIES OF RICE FARMERS IN EBONYI STATE, NIGERIA.

MASTER'S THESIS

Prague 2024

Author: **Amah-Jerry, Egwuchukwu Peace**

Chief supervisor: doc. Ing. Miroslava Bavorová, Ph.D.

Declaration

I hereby declare that I have done this thesis entitled *“Assessment of Climate Change Adaptation Strategies of Rice Farmers in Ebonyi state, Nigeria”* independently. All texts in this thesis are original, and all the sources have been quoted and acknowledged by means of complete references and according to Citation rules of the FTA.

In Prague 2024

…………………………………………

Amah-Jerry Egwuchukwu Peace

Acknowledgments

I would like to thank my Thesis Supervisor doc. Ing. Miroslava Bavorová, Ph.D. for her multiple nudges which helped ensure I crossed the finish line. I am particularly indebted to her for being instrumental in ensuring that I received a 10,000 CZK grant which helped cushion the cost from mobilizing enumerators for the data collection.

To the entire Faculty Board, I thank you all for the grace to tidy up my studies. I would also like to thank Mrs. Ilona Marková of the Study Department for the role she played in ensuring that I completed my study programme. I am sincerely grateful.

To my lovely wife Chioma and my adorable daughter Pearl, I say a big thank you for your understanding and support. To my amazing colleague Klára Kalinová, who always made time to check up on me and the progress of my work, I say a big thank you to you. Those gestures may seem casual, but they meant a lot to me.

More so, to my friend and colleague, Dr. Chinedu Nwogu, thank you for working hand in glove with the trained enumerators from the Agricultural Development Programme (ADP), and supervising their activities to ensure that data for this research was collected effectively and efficiently. In addition to this, I am indebted to Dr. Samuel Ahado who found time to read through my work and suggested corrections where necessary. Your resilient efforts and contributions no doubt made the final version of this thesis better.

To my parents Dr. Jerry and Dr. (Mrs.) Chiawolam Amarikwa and my siblings, Ezinwanne, Douglas, Donald, and Eziaha, I am excited about your unalloyed support in the times when I needed the push to carry on. I will remain forever grateful to God for the gift of you all in my life.

Thank you all for your support.

Finally, to myself, I am glad I carried on until the end. I am proud to finally become the first in my family and entire kindred to earn a degree from an international institution. This could be a record I will hold for a long time to come.

Abstract

This study was conducted to assess rice farmers' adaptation strategies to climate change in Ebonyi state, Nigeria. The multistage sampling technique was used to select 240 respondents comprising 126 beneficiaries and 114 non-beneficiaries of the FADAMA III project. Data collected were analyzed using simple descriptive tools such as tables, charts, means, frequencies, and percentages as well as econometric tools such as multiple regression, and the Chow's test. Notable adaptation strategies used by farmers were early planting, planting of improved varieties, the combined use of organic and inorganic fertilizers, adjustments in planting and harvesting schedules, and livelihood diversification. The regression estimates of productivity determinants showed that the coefficient of farm size was positive for the pooled farmers, beneficiaries, and non-beneficiaries at 1 percent, 10 percent, and 1 percent levels of significance respectively. The coefficient of credit was positively related to the level of productivity of the farmers. Extension contacts positively and significantly influenced beneficiaries and non-beneficiaries productivity in rice production. Also, labour and capital were seen to have a negative influence on the productivity of the farmers with capital negatively influencing the productivity of the pooled and non-beneficiaries of the project at a 1 percent level of significance while capital similarly influenced negatively the productivity of beneficiaries and the pooled respondents. The result also showed that there was a significant effect of the FADAMA III project on the rice farmers' productivity. It was recommended that climate change adaptation strategies be mainstreamed into agricultural policies, plans, and programs designed to enhance agricultural productivity and profitability. Governmental prioritization of programs aimed at improving farmers' productivity, such as the FADAMA program, should be emphasized to support agricultural resilience in the face of climate change.

Contents

List of tables

List of figures

List of the abbreviations used in the thesis

Acronym	Full meaning
HH	Household size
LGA	Local Government Area
FAO	Food and Agriculture Organization
IFAD	International Fund and Agricultural Development
IPCC	Intergovernmental Panel for Climate Change
TFP	Total Factor Productivity

1. Introduction and Literature Review

1.1. Introduction

Rice is a major source of income for millions of farming households around the world and a very high exchange earner for producing countries. Thus, rice is both a strategic economic and political commodity. In Africa, rice occupies a central place in the diets of many families, while others consider it a food of luxury, usually served on special occasions and festivals. Rice has become a very important commodity in most Nigerian households due to its ease of production and use as food for consumption (Kadiri et al., 2014).

Grown in virtually all ecological zones of Nigeria, Onyishi et al. (2010) assert that the main rice production ecologies are rain-fed lowland, rain-fed upland, irrigated lowland, floating deep water, and mangrove swamps. They also observed that the area cultivated under rain-fed upland is 25 percent, rain-fed lowland 50 percent, irrigated lowland 16 percent, deep water, and mangrove 9 percent, and their share of production is 17 percent, 35 percent, 27 percent, and 3 percent for rain-fed upland, rain-fed lowland, irrigated lowland, and deep-water mangrove respectively. Undoubtedly, rice is one of the most important cereal crops and ranks high on the list of foods of high-calorie content in Nigeria, where there is a very high dependence on staple food crops and agriculture (Saito et al., 2015; Onyeneke et al., 2021, 2022).

In Nigeria where agriculture alone contributed about 22.35 percent of real gross domestic product value in the first quarter of 2021 (National Bureau of Statistics Nigeria, 2021), climate change becomes a damaging challenge given the heavy reliance on the expected “normal weather condition” for agricultural activities. This heavy dependence on weather is therefore a leading cause of declining crop yield and farm incomes, food production and food supply (Kima et al., 2014; Mulenga et al., 2017; Ayanlade et al., 2018). Substantial evidence of climate change impacts on rice exists. For instance, researchers have identified these specific challenges to include decline in rice yield, significant crop income losses and reduction in grain quality (Kima et al., 2014; Harvey et al., 2014; and van Oort and Zwart, 2018), thus, the need for adaptation strategies to climate change effects on rice production.

Climate change adaptation are deliberate efforts to reduce the detrimental effects of climate change on agriculture (Kurukulasuriya and Mendelsohn, 2007) with the aim of protecting poor farmers' livelihoods, reduce vulnerability to failures and shocks and reinforce all farm-benefits available to the farmer (Gandure et al., 2013; Wheeler et al., 2013). In a broader sense, adaptation is effective in mitigating prolonged exposure to gradual climate change (salinization and sea-level rise) as well as extreme climatic events and shocks like floods and droughts (Branca et al, 2012). Adaptive capacities will therefore reduce the vulnerability and exposure of the agricultural system to harmful external environments (Adger et al, 2007; OECD, 2009) and therefore reduce the risk-severity index of climate related hazards and consequences.

In Ebonyi state Nigeria, smallholder rice farmers combine locally made and conventional adaptation strategies to cope with the debilitating effects of climate change. Most of these strategies as identified by literature include changing of planting dates, early rice varieties, mixed cropping, the use of organic/chemical fertilizers, varieties of drought-tolerant rice, farming near water bodies to achieve enhanced irrigation, the establishment of shallow tube wells in a pond, the construction of dams, crop rotation, tree integration on rice farms, and species of a short duration (Below et al, 2010; and Ghosh et al, 2017). These strategies therefore are efforts targeted at reducing the unacceptably high declining productivity in rice farming vis-à-vis selected government projects in the state.

The low level of investment in the agricultural sector has contributed to the very low productivity encountered in rice production in addition to the problems of financing, processing, and marketing which has hindered the full maximization of the rice potentials (Saheed et al., 2018). Rice is a major staple food among African countries and remains the most consumed food across the tribes and regions of Nigeria (Lu et. al., 2018, FAO, 2019). Its importation, though a major business activity in Nigeria has negatively affected local rice production which should have provided a major boost to meeting the country’s rice demand gap.

In her attempts to increase food productivity, the Nigerian government made some prominent interventions to increase crop productivity, generate employment, ensure food security and ameliorate poverty. Some of the interventions included – The Green Revolution, Lower Niger River Basin Development Authority (LNRBDA), Operation Feed the Nation (OFN), and regulatory bodies such as the Directorate of Foods, Roads, and Rural Infrastructure (DFRRI) and National Agricultural and Land Development Authority (NALDA). Massive failures owing to institutional weaknesses, corruption and poor implementation were recorded about the interventions (Aderinoye-Abdulwahab, 2020). With rice in the spotlight, it cannot be argued that there are failed rice interventions where the provided inputs did not get to the intended beneficiaries. There have been obvious cases of inputs losses by farmers after disbursement, mismanagement of funds by programme managers as well as poor disbursement to the farmers (FMARD, 2018). This has forced the farmers to secure inputs at a higher interest rate, limited accessible credit and inconvenient demand for collateral among others.

The World Bank have contributed in some way to finance projects targeted at ensuring increased rice production in major states in Nigeria. The World Bank’s FADAMA project in Nigeria which is currently in its third phase (FADAMA III) is focused on increasing rice production, creation of employment opportunities, encourage access to and adoption of improved rice varieties and ultimately, poverty alleviation (World Bank, 2013).

How much these projects have impacted the lives of the beneficiaries (particularly rice farmers), especially, in raising their living standards and alleviating rural poverty while emphasizing climate change adaptation strategies is yet to be quantitatively determined.

Sadly, Sub-Sahara African agricultural systems are terribly plagued by climate change which have manifested in various forms such as drought, erratic rainfall patters, flooding, and rising temperatures (Niang et al., 2014). The effect on rice production is of more terrifying.

Climate change is a global phenomenon with a progressive negative impact on agriculture (Ghile et al., 2014; Dai and Zhao, 2017; Onyeneke, 2010), environment, natural resources, livelihood activities, and food security (Ashrafuzzaman and Furini 2019; Schnitter and Berry 2019; Sujakhu et al. 2019; Anungwa et al. 2020). In some parts of the world, especially, south of Sahara, there are issues of hot-dry conditions at the onset and cessation of rains (Allen, 2015) with resultant flood sessions and prolonged dry periods (Fuwape et al., 2016).

1.2. Literature Review

1.2.1. Climate Change

Climate change is a pressing global issue with far-reaching implications for ecosystems, societies, and economies. The literature on climate change spans across various disciplines and provides extensive evidence on the causes, impacts, and mitigation strategies related to this phenomenon.

Literatures have established the fact that this change is primarily driven by human activities, particularly the emission of greenhouse gases (GHGs) into the atmosphere and research as documented by IPCC (2021) has demonstrated that the burning of fossil fuels for energy production, deforestation, industrial processes, and agricultural practices contribute significantly to GHG emissions. In addition, urbanization, and changes in the use of land have further escalated these impacts (Bhattacharjee et al. 2022).

These impacts include changes in temperature, precipitation patterns, sea-level rise, increased frequency of extreme weather events, and disruptions to ecosystems and biodiversity (IPCC, 2021).

The effects of climate change cuts across all sectors and regions as it affects agriculture, water resources, public health, infrastructure, and socio-economic systems, thereby posing significant challenges to sustainable development and the well-being of human at large (IPCC, 2021; FAO, 2022) with vulnerable populations, particularly in developing countries, bearing the brunt of these impacts (UNDP, 2022; World Bank, 2022).

The time-lagged nature of climate change implies that the currently observed climate change is attributed to greenhouse gas emission of the 19th and 20th centuries and that the effects of current greenhouse gas emissions will also lag into the future. That being said, the implication is that a focus on the mitigation of climate change alone will not be sufficient to address its current impacts. Hence, there is a need to adapt to adjustments that moderately harm or exploit beneficial opportunities (IPCC, 2021).

The United Nations Framework Convention on Climate Change (UNFCCC) on May 9, 1992 adopted adverse effects of climate change to mean the changes in the physical environment or biota which have significant deleterious effects on the composition, resistance, or productivity of natural and managed ecosystem or on the operation of socio-economic systems or on human health and welfare (UNFCCC, 2021). In the second article of the convention, it aimed at achieving the stabilization of greenhouse gas concentration in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level is expected to be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change to ensure that food production is not threatened while also enabling economic development to proceed in a sustainable manner.

1.2.2. Climate Change Adaption Practices

Farmers' vulnerabilities to the effects of climate change can be minimised by adapting to climate change strategies. This has led several countries to place an emphasis on strategic plans and actions aimed at reducing susceptibility in various sectors, communities, and regions. In the state of Ebonyi, for example, communities have traditionally used indigenous and local adaptation measures to cope with climate risks

(Choko et al., 2019). However, given the increasing impact of climate change and the uncertainties involved, these traditional responses may not suffice for effective adaptation (Tarfa et al., 2019). Addressing the current severity of climate impacts and anticipated vulnerabilities is essential, as existing indigenous methods may fall short. Enhancing community resilience not only facilitates adaptation, but also aligns with the goals of agricultural development programmes in the Ebonyi state, offering a way forward amidst the challenges posed by climate change.

Undoubtedly, the significance of adaptation in the management of climate change cannot be overstated. Researchers have directed attention to the vulnerability of rice production in the face of climate change, particularly noting its high sensitivity in regions like sub-Saharan Africa (Terdoo and Feola, 2016). Consequently, there is a pressing need to mitigate the vulnerability of the rice sector to climate change. Adapting rice production practices is essential for augmenting farmers' yields and ensuring food security. Across various parts of the world, farmers employ diverse local adaptation practices to manage climate risks. These practices encompass minimum tillage, drainage and bund construction, the combined use of organic and inorganic fertilizers, crop diversification, utilization of improved rice varieties, nursery cultivation, application of pesticides, livelihood diversification, and adjustments in planting and harvesting schedules (Oselebe et al., 2016; Roco et al., 2017; Unique-Kulima, 2017; Quan et al., 2019; Rondhi et al., 2019; Teklewold et al., 2019).

Numerous researchers have emphasized the significance of adopting minimum tillage practices, attributing benefits such as flood and erosion control, improved soil fertility, heightened climate resilience, and environmental conservation to this approach (Verhulst et al., 2012; Kuntashula et al., 2014; Richards et al., 2014). Additionally, employing a combination of organic and chemical fertilizers emerges as a crucial strategy for adapting to climate change in agricultural production. The impact of climate change, characterized by heightened flooding, erosion, runoff, and soil nutrient loss, contributes to soil fertility depletion, adversely affecting essential soil properties such as pH, water holding capacity, and bulk density (Brevik, 2013; García-Fayos and Bochet, 2009). The judicious application of organic and chemical fertilizers, ensuring they are sourced correctly, applied at the right rate, and at the appropriate time and location, serves to enhance soil fertility. This, in turn, leads to increased crop yields, ultimately diminishing farmers' vulnerability to the adverse effects of climate change.

Similarly, improved rice varieties have been used by many farmers in managing climate risks (Unique-Kulima, 2017; Aryal et al., 2018). Early maturing rice varieties, for instance, are better suited for managing delayed onset and early cessation of rain that now characterize agricultural production in many parts of Nigeria (Babatunde et al., 2011; Tarfa et al., 2019).

Researchers have extensively focused on the establishment of local drainage systems and bunds as a means of mitigating climate risks in agricultural systems (Iglesias and Garrote, 2015; Roesch-Mcnally, 2016; Mo et al., 2017; Onyeneke et al., 2018a). Implementing these methods serves to mitigate flooding and erosion on agricultural land and farms, improving farmers' ability to withstand the impacts of climate change (FAO, 2012; Iglesias and Garrote, 2015; Morton et al., 2015; Roesch-Mcnally, 2016; Mo et al., 2017; Roesch-Mcnally et al., 2017; Onyeneke et al., 2018a).

Crop diversification proves effective in mitigating the impact of climate change on farmers, contributing to their resilience (Belay et al., 2017; Fadina and Barjolle, 2018; Tarfa et al., 2019). In the context of rice production, crop diversification plays a key role in adaptation to climate change by distributing production and income risks across various crops, thus reducing farmers' vulnerability (Lin, 2011; FAO, 2018; Waha et al., 2018; Huang et al., 2014). Similarly to the benefits of crop diversification, participating in various livelihood activities protects farmers from climate shocks, as demonstrated by studies such as Lasco et al. (2011), Idoma et al. (2017), Fadina and Barjolle (2018), and Ho and Shimada (2019). Diversification of living standards improves farmers' resilience by spreading both their income and production risks (Nigerian Environmental Study Action Team and Woodley, 2012). Furthermore, incorporating the use of nurseries in rice production helps farmers adapt to climate uncertainties (Deng et al., 2017; Oselebe et al., 2016; Bhandari, 2009). By initially nurturing rice seedlings in a nursery before transplanting them to the field, farmers gain valuable insight to make informed decisions on transplantation based on climate risks, optimising the timing and conditions for the process.

The incidence of pests and diseases is on the rise due to climate change, leading to the emergence of new pests and insects in crops (Harvey et al., 2014; Warren et al., 2018; Ibrahim, 2014; Macfadyen et al., 2018; Heeb et al., 2019). As the prevalence of crop pests and diseases increases, so does the demand for pesticides. Effective use of pesticide combinations, coupled with appropriate application rates, timing, and location, not only preserves the environment and soil but also contributes to climate resilience and increased crop yields (Heeb et al., 2019). Researchers have documented the use of pesticides as a strategy for climate change adaptation (Dhakal et al., 2016; Bhandari, 2009; Fadina and Barjolle, 2018). Climate change is altering the variability, pattern, and distribution of rainfall in sub-Saharan Africa (Choko et al., 2019; Onyeneke et al., 2017).

The altered rainfall patterns witnessed in sub-Saharan Africa are influencing rice agronomic practices, specifically the timing of planting and harvesting. To cope with the changing patterns in rainfall duration and distribution, farmers are adopting the strategy of modifying their planting and harvesting schedules. This adaptive approach is widely embraced among farmers in developing nations (Arimi, 2014; Ezeh and Eze, 2016; Mbah and Ezeano, 2018; Gahatraj et al., 2018; Tarfa et al., 2019).

The relationship between climate change and food security is complex. Changes in temperature and precipitation patterns can directly affect agricultural productivity, influencing food availability and access. Vulnerable populations are particularly susceptible to fluctuations in food security linked to climate variability (Wheeler & von Braun, 2013).

Education serves as a fundamental tool in building resilience to the impacts of climate change. Hence, educated communities are better equipped to understand and adapt to changing environmental conditions, enhancing their ability to sustain livelihoods (Barrett, Reardon, & Webb, 2001).

1.2.3. The FADAMA Intervention Project

The term FADAMA is derived from the Hausa language meaning "valley bottoms." It is an agricultural intervention project in Nigeria, designed specifically to enhance food security, alleviate poverty, and improve the livelihoods of rural communities. It operates with support from international organizations like IFAD, and its role is pivotal in the context of rice farming in Ebonyi state, Nigeria.

The project is devoted to empowering smallholder farmers by providing them with access to improved agricultural practices, technology, and market linkages (Abdoulaye et al., 2018). A significant aspect of the FADAMA interventions is the promotion of irrigated rice production, from harnessed water resources, thereby mitigating the risks associated with rain-fed agriculture and contributing to increased food productivity (Abdoulaye et al., 2018). FADAMA projects emphasize community participation and collaboration. Engaging local communities in decision-making processes and fostering collaborative efforts contribute to the success and sustainability of agricultural interventions (Akpokodje et al., 2012).

Various factors such as climatic conditions, access to resources, and the adoption of modern farming techniques influence the productivity of rice farmers (Oladele et al., 2020). Technologies such as improved seed varieties, mechanized farming equipment, and precision agriculture contribute to increased yields and efficiency (Doss et al., 2018) just as effective water management is crucial for rice cultivation.

In a recent study by IFAD (2022), it was revealed that the FADAMA IFAD projects helped to address the issues of gender disparities as it provided training resources for women, thus, leading to women empowerment and enhancing their participation and decision making in agriculture. In addition, empirical evidence from Okonofua and Isikwue (2022) suggested that beneficiaries from the FADAMA IFAD projects become empowered to engage in off-farm activities which help to contribute and improve their overall livelihood.

The programme also fostered community cohesion through the training it provided, thereby creating safety nets which contributed to the well-being of the beneficiaries (IFAD, 2020).

2. Aims of the Thesis

The broad objective of the study was to assess the climate change adaptation strategies of rice farmers in Ebonyi state, Nigeria, while the specific objectives were to:

1. assess the perception of the rice farmers to climate change.
2. identify the climate change adaptation strategies among the rice farmers.
3. examine the level of productivity among the rice farmers.
4. analyse the factors that determine the productivity of the rice farmers.
5. examine the impact of FADAMA III on the productivity of the rice farmers.

The study will aim to answer questions on the following:

1. what is the perception of the rice farmers to climate change?
2. what are the climate change adaptation strategies used by the rice farmers in the study area?
3. what is the productivity level of the rice farmers?
4. What are the factors that determine the productivity of the rice farmers?
5. what is the impact of FADAMA III project on the productivity of rice farmers in the study area?

3. Methods

3.1. Study Area

The study was carried out in Ebonyi State, Nigeria. In 2016, the Statistical Bulletin of the Central Bank of Nigeria pegged the population of the State at 2,880,383 persons (Central Bank of Nigeria, 2016). The state shares boundaries with Abia State and Cross River State in the east, Abia State in the south, Enugu State in the west, and Benue State in the north. As shown in Figure 2, it has 13 Local Government Areas and 3 agricultural zones namely Ebonyi North (comprising of Izzi, Abakaliki, Ohaukwu and Ebonyi Blocks): Ebonyi Central (comprising of Ishielu, Ikwo, Ezza South and Ezza North Blocks) and Ebonyi South (comprising of Afikpo, Afikpo South, Onicha and Ohazara Blocks).

The State has a land mass of approximately 5,932km^2 and lies within latitudes 4^{1}N and 14^{1}N of the Equator and longitudes 3^o E and 15^0 E of Greenwich meridian. It enjoys an average rainfall of 1200mm – 2000mm with temperatures ranging from 33^{o}C in the dry season and about 16^{o}C to 18^{o}C in the rainy season (EBADEP Annual Record, 2005).

The population which is predominantly Igbos and Christians have diverse occupations with a significant proportion of them being farmers (especially in rice, yam, cassava, and palm kernel). These agricultural practices are influenced by seasons. The population comprises predominantly Igbo and Christians.

Figure 1: Map of Nigeria highlighting Ebonyi state (in RED)

Figure 2: Map of Ebonyi state showing the 13 Local Government Areas

3.2. Data Collection

3.2.1. Data Sources

Primary data was used for this study.

3.2.2. Instrument for Data Collection

Data for the study was collected with the aid of a well-structured questionnaire built into the Kobo collect application (a mobile data collection tool). This tool is used to track, create, and manage mobile forms or surveys even when offline.

The mobile application was adopted mainly because it has several advantages; first it saves cost from printing paper questionnaires and ensures data is not lost on transit as it can be used both in offline and online states. Moreso, it is user friendly and easy to demonstrate its operation to the enumerators. To crown it all, the mobile application has a GPS feature which helped to ensure that the data were generated from the target respondents and not manipulated by the enumerators.

Enumerators for the data collection were recommended by the ADP authorities in Ebonyi state on grounds that they were familiar to the use of similar data capturing technology. Six (6) enumerators (one for each Local Government Area) were recruited and trained by an academic staff of the Alex Ekwueme Federal University, Ndufu – Alike, Ikwo in Ebonyi state, who was tasked also with the supervision of the data collection.

The questionnaire captured information on the socio-economic profiles of the rice farmers, their perception to climate change, the climate change adaptation strategies used, farmers' productivity levels and its determinants, and exact GPS locations where the data were collected. This information was captured and uploaded in real time to the backend of the kobo collect application.

3.2.3. Selection of Respondents

The respondents for the study were selected using the multistage sampling technique. The selected respondents were farmers who benefited from rice projects/ interventions (in this case FADAMA III) and those who did not benefit from the project.

In the first stage, 6 Local Government Areas (2 from each agricultural zone) were purposively selected based on the level of rice production and their involvement in some of the targeted rice intervention projects. In the second stage, 2 blocks each known for high rice production and high number of project beneficiaries were purposively selected from the 6 selected LGAs, summing a total of 12 blocks. From these blocks, 2 circles each were randomly selected, summing a total of 24 circles.

Initially in the proposal, 5 beneficiaries and 5 non-beneficiaries were supposed to be selected from each circle to give a total of 120 beneficiaries and 120 non-beneficiaries each. However, during the actual data collection, data were collected from 126 beneficiaries and 114 non-beneficiaries, giving a total of 240 respondents.

3.3. Data Analysis and Model Specification

For the data analysis, simple descriptive tools such as tables, frequencies, percentages, and means, as well as econometric tools such as multiple regression, and the Chow's Test were employed.

Descriptive statistics were used to assess the perception of the rice farmers to climate change and to identify their adaptation strategies to climate change. Furthermore, the ratio of the total output to the total input used in the production process was used to estimate the level of productivity of the rice farmers in the study area. This was calculated using the Total Productivity (TFP) analysis.

The choice of the TFP analysis was because it considers the output to the input ratio and not the production function. That is, it does not focus on production variables as they are not the only factors that affect productivity unlike the production function that tends to consider only the production estimators (factors of production).

The TFP is given below:

$$TFP = \frac{Y}{\sum P_i X_i} \quad \text{.......... (3.1)}$$

Where,

Y = Value of crop in naira,

P_i = unit price of the i^{th} variable input,

X_i = quantity of the i^{th} variable input.

Thus,

$$\text{Total Factor Productivity (in naira)} = \left(\frac{total\ output}{total\ input}\right) \quad \text{.......... (3.2)}$$

Subsequently, factors affecting the productivity level of the rice farmers will be achieved using the Ordinary Least Square regression method using diverse econometric specifications, namely, the linear, double log, semi-log, and exponential functional forms. The model that gave the best fit will be selected as the best equation.

The model is described thus:

TFP = $(X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, X_{10}, X_{11})$ .... (3.3)

Where,

TFP = Total Factor Productivity i.e ($\frac{total\ rice\ output}{total\ rice\ input}$), measured in naira

X_1 = Farm size in hectare,

X_2 = Labour (man days),

X_3 = Capital input (naira) (made up of capital consumption allowance, rent, interest),

X_4 = Age of the farmers in years,

X_5 = Credit access (1= access, 0 = non access),

X_6 = Educational attainment (years),

X_7 = Farmer experience (number of the years of farming),

X_8 = Household size of the farmer family,

X_9 = Sex (male = 1, female = 0),

X_{10} = Number of extension contacts,

X_{11} = adaptation strategies (number)

To examine the impact of the FADAMA III project on the productivity of rice farmers in the study area, the Chow's Test was employed for the exercise.

The Chow's Test is given as follows:

$$F = \frac{[(Ee_3^2 - (Ee_1^2 + Ee_2^2)] / K_3 - K_1 - K_2}{(Ee_1^2 + Ee_2^2) / K_1 + K_2} \quad \text{...} (3.4)$$

Where,

Ee_3^2 and K_3 = the error sum of square and degree of freedom respectively of the pooled data.

Ee_1^2 and K_1 = the error sum of square and degree of freedom for FADAMA rice farmers.

Ee_2^2 and K_2 = the error sum of square and degree of freedom for non-FADAMA rice farmers

Decision rule: If the calculated F (*f cal*) exceeds the tabulated F (*f tab*), reject the null hypothesis of no difference in the productivity of the two subgroups.

For test of homogeneity of slope, the Chow's F- statistic is as follows:

$$F = \frac{[(Ee_4^2 - (Ee_1^2 + Ee_2^2)] / K_4 - K_1 - K_2}{(Ee_1^2 + Ee_2^2) / K_1 + K_2} \quad \text{...} (3.5)$$

Where Ee_4^2 and K_4 = the error sum of square and degree of freedom respectively for the pooled data with a dummy variable of value one (1) for FADAMA III rice farmers and zero (0) for non-FADAMA III rice farmers. Other variables are as earlier defined.

Decision rule: If the calculated F (*f cal*) exceeds the tabulated F (*f tab*), reject the null hypothesis of no structural change or shift in profit parameter.

For the test of differences in intercepts, the Chow's F-statistics is calculated as follows:

$$F = \frac{[(Ee_3^2 - Ee_4^2)] / K_3 - K_4}{(Ee_4^2 / K_4)} \qquad \text{.......} \quad (3.6)$$

All variables as earlier defined.

Decision rule: If the calculated F (*f cal*) exceeds the tabulated F (*f tab*), reject the null hypothesis of no difference in the productivity of FADAMA III rice farmers and non-FADAMA III rice farmers.

4. Results

4.1. Perception of the Rice Farmers to Climate Change

The respondents were asked to state their perceived existence of climate change. The result is presented in Table 1.

Table 1: Perception of the Rice Farmers to Climate Change

	Pooled (%)			Beneficiaries (%)			Non-beneficiaries (%)		
Climate change statements	**IDA**	**IDK**	**IA**	**IDA**	**IDK**	**IA**	**IDA**	**IDK**	**IA**
The mean temperature has increased in recent years.	0	0	100	0	0	100	0	0	100
The average precipitation has increased in recent years.	1	0	99	2	0	98	0	0	100
Recent years have seen a higher occurrence of unseasonal and unpredictable rainfall.	11	1	88	13	1	86	10	0	90
Floods, droughts, and storms have become more frequent in recent years.	1	1	98	1	1	98	1	0	99
The dry season now arrives earlier than it did a decade ago.	43	3	54	43	2	55	44	4	52

Salinity intrusion has become more frequent in recent years than ten years ago.	33	4	63	34	1	65	31	8	61
Floods can contribute to making land more infertile.	1	0	99	1	1	98	0	0	100
Irregular timing of seasons and salinity can result in a decrease in crop productivity.	0	0	100	0	0	100	0	0	100
Higher temperatures can lead to an increase in diseases for humans, crops, and livestock.	0	0	100	0	0	100	0	0	100
Floods, droughts, and storms can cause damage to crops.	0	0	100	0	0	100	0	0	100
Longer droughts can lead to a reduction in crop output.	0	0	100	0	0	100	0	0	100
Climate change can be caused by poor natural resource management.	0	0	100	1	0	99	0	0	100

Source: Field survey, 2024. Key: IDA = I don’t agree; IDK = I don’t know; IA = I agree

4.2. Climate Change Adaptation Strategies of the Rice Farmers

In an effort to minimise the adverse effects of climate change and variability on rice production in the Ebonyi state, these farmers employed several strategies to cope with climate change and the results were presented in Table 2.

Table 2: Climate Change Adaptation Strategies of the Rice Farmers

	Beneficiaries (n=126)		Non-beneficiaries (n=114)		Pooled (n=240)	
Adaptation strategies	**Freq.**	**Percent**	**Freq.**	**Percent**	**Freq.**	**Percent**
Early planting	118	94	108	95	226	95
Planting of improved varieties	125	99	110	96	235	98
Minimum tillage	77	61	58	51	135	46
Drainage and bund construction	110	87	90	79	200	83
The combined use of organic and inorganic fertilizers	119	94	103	91	222	93
Crop diversification/ growing a variety of crops	126	100	109	96	235	98
Nursery cultivation	78	62	80	70	157	66
Adopting water conservation practices	121	96	110	96	231	96
Adjustments in planting and harvesting schedules	126	100	110	97	236	99

Livelihood diversification	124	98	111	97	234	98
Planting trees	125	99	13	99	238	99
Mulching/ use of cover crops	118	94	110	96	227	95
Irrigation	33	26	46	41	79	33
Land rotation	78	62	78	70	156	66

Source: Field survey, 2024

4.3. Productivity Level of the Rice Farmers

The productivity of the rice farmers is calculated as the ratio of their total production to the total input used in the production process. The monetary approach was adopted to estimate the level of productivity of the farmers. In this case, the ratio of the output and input prices were determined respectively, and results presented in Table 3.

Table 3: Productivity Level of the Rice Farmers in Ebonyi State

	Beneficiaries (n=126)		Non-beneficiaries (n=114)		Pooled (n=240)	
Level of productivity	**Freq.**	**Percent**	**Freq.**	**Percent**	**Freq.**	**Percent**
≤ 10	78	62	93	82	171	71
10.00 – 19.99	46	36	21	18	67	28
20.00 – 29.99	2	2	0	0	2	1
Mean productivity	**6.28**		**5.60**		**6.28**	

Source: Field survey, 2024.

4.4. Determinants of Productivity of Rice Farmers in Ebonyi State

To determine the factors that affect the productivity of rice farmers in the Ebonyi state, the multiple regression model was used. Four functional forms of the multiple regression model (Linear, Semi-log, Exponential, and Double log) were tested. The best fit was selected based on a number of econometric and statistical criteria such as number of significant variables, value of R^2 and signs and magnitude of the variables as they conform to economic theory. The results are presented in Tables 4, 5 and 6.

4.4.1. Determinants of Productivity for Pooled Rice Farmers in Ebonyi state

To determine the factors that affected the productivity of the pooled rice farmers in the study area, the double log functional form was selected as the best fit for the pooled farmers. The result from the table is reported below. The F-ratio was statistically significant at 1 percent indicating a high goodness of fit of the regression line.

Table 4: Determinants of Productivity for Pooled Rice Farmers in Ebonyi State

	Linear	Exponential	Semi-log	Double log (+)
Gender (1 = male, 0 = female)	381.1822	-.0478008	343.8483	-.0509346
	(0.72)	(-0.32)	(0.66)	(-0.37)
Age of the household head (in years)	-.1508975	-.007985	-187.0661	-.377849
	(-0.00)	(-0.75)	(-0.11)	(-0.87)
Education (years)	-51.1825	-.0062206	-118.0094	-.049776
	(-0.95)	(-0.41)	(-0.36)	(-0.57)

Household size (in number)	-92.52227	-.0124974	-538.4855	-.005141
	(-0.67)	(-0.32)	(-0.55)	(-0.02)
Farmer experience (in years)	-40.36716	.0093143	-418.4737	.0871464
	(-0.81)	(0.66)	(-0.49)	(0.39)
Farm size (in hectares)	234.1601	.23657	1154.378	.8791673
	(0.68)	(2.43**)	(2.46**)	(7.08***)
Access to credit (1 if yes, 0 if no)	-152.4452	-1.97765	504.2027	-1.535566
	(-0.28)	(-12.68***)	(0.84)	(-9.69***)
Number of extension contacts	515.781	.4458129	167.822	.1522502
	(0.92)	(2.82**)	(0.29)	(1.00)
Labour (man days)	-.0013628	-1.76e-07	-1704.439	-.6109682
	(-0.94)	(-0.43)	(-3.15***)	(-4.27***)
Capital input (naira)	-.0007594	2.15e-06	101.8559	-.0174541
	(-0.07)	(0.72)	(0.61)	(-0.39)
Adaptation strategies (in number)	-46.86432	-.0623578	652.9104	.1800352
	(-0.19)	(-0.87)	(0.23)	(0.24)
FADAMA III (Beneficiaries = 1; Otherwise = 0)	-288.1301	-.4589291	-124.7446	-.3610886
	(-0.52)	(-2.93***)	(-0.23)	(-2.49**)
Constant	2483.92	2.940738	22146.12	11.02967

	(0.76)	(3.21***)	(2.17**)	(4.09***)

Source: Field survey, 2024. *** = 1 percent, ** = 5 percent and * = 10 percent level of significance respectively.

4.4.2. Determinants of productivity for FADAMA III benefitting rice farmers

To determine the factors that affected the productivity of FADAMA III benefiting farmers in the study area, the exponential form was selected for the beneficiaries the project. The result from the findings is displayed in Table 5 as below:

Table 5: Determinants of Productivity for FADMA III benefitting Rice Farmers

	Linear	Exponential (+)	Semi-log	Double log
Gender (1 = male, 0 = female)	437.0475	.2290099	518.6039	.1686532
	(0.38)	(0.77)	(0.47)	(0.64)
Age of the household head (in years)	-24.68931	-.0250645	-2238.358	-1.212601
	(-0.35)	(-1.35)	(-0.72)	(-1.61)
Educational level (in years)	-103.2315	-.0238216	-167.4795	-.0824717
	(-1.00)	(-0.89)	(-0.29)	(-0.58)
Household size (in number)	-213.0646	-.0649223	-167.4795	-.2524716
	(-0.73)	(-0.92)	(-0.69)	(-0.54)
Farmer experience (in years)	-55.36606	.0207139	-140.0751	.3799296
	(-0.63)	(0.91)	(-0.09)	(1.04)

Farm size (in hectares)	774.7226	3144298	2341.288	1.264018
	(1.09)	(1.70*)	(2.69**)	(6.02***)
Access to credit (1 if yes, 0 if no)	-210.9272	-1.765042	1243.428	-1.080027
	(-0.20)	(-6.42***)	(1.07)	(-3.85***)
Number of extension contacts (in numbers)	968.8149	.5177408	126.5866	.137844
	(0.85)	(1.75*)	(0.11)	(0.51)
Labour (man days)	-.0049208	-2.67e-07	-3895.044	-1.145827
	(-1.25)	(-0.26)	(-3.49***)	(-4.26***)
Capital input (naira)	.0038035	2.61e-06	175.2091	.0060211
	(0.23)	(0.62)	(0.60)	(0.09)
Adaptation strategies (in number)	.2299768	-.2532445	3634.353	-.7642623
	(0.00)	(-1.79*)	(0.57)	(-0.50)
Constant	4880.52	5.757741	50201.77	22.37216
	(0.69)	(3.15***)	(2.38**)	(4.40***)

Source: Field survey, 2024. *** = 1 percent, ** = 5 percent and * = 10 percent level of sig. respectively.

4.4.3. Determinants of productivity for non - FADAMA III benefitting rice farmers

To determine the factors that affected the productivity of non – FADAMA III benefiting farmers in the study area, the exponential form was also selected, and the result is displayed in the Table 6 as below:

Table 6: Determinants of Productivity for Non – FADAMA III benefitting Rice Farmers

	Linear	Exponential (+)	Semi-log	Double log
Gender of the HH (1 = male, 0 = female)	-.4845499	-.0220462	-.5347803	-.0340896
	(-0.90)	(-0.19)	(-1.07)	(-0.31)
Age of the HH (in years)	.0380196	.0113829	1.413253	.3535334
	(0.88)	(1.22)	(0.79)	(0.90)
Educational level (in years)	-.1139618	-.0688463	-.1945081	-.1348695
	(-0.37)	(-1.03)	(-0.29)	(-0.90)
Household size (in number)	.1242912	.0100815	.5450254	.039446
	(0.92)	(0.34)	(0.60)	(0.20)
Farmer experience (in years)	-.0579687	-.02176	-1.093639	-.3173747
	(-0.94)	(-1.63)	(-1.16)	(-1.52)
Farm size (in hectares)	1.388108	.3414713	2.181009	.488549
	(2.64**)	(3.01***)	(4.40***)	(4.46***)
Access to credit (1 if yes, 0 if no)	-5.933235	-2.083158	-5.369698	-1.931954

	(-9.41***)	(-15.30***)	(-8.88***)	(-14.45***)
Number of extension contacts (in numbers)	1.492859	.228364	.4028618	.0209682
	(2.46**)	(1.74*)	(0.67)	(0.16)
Labour (man days)	-1.90e-06	-5.05e-07	-.7691725	-.2602802
	(-1.51)	(-1.86*)	(-1.53)	(-2.34**)
Capital input (naira)	-.0001603	-.0000335	-.3703418	-.0336538
	(-2.56**)	(-2.48**)	(-1.81*)	(-0.74)
Adaptation strategies (in numbers)	-.2385681	-.0196248	-.7785298	.1558338
	(-0.99)	(-0.38)	(-0.30)	(0.28)
Constant	8.314993	1.973632	19.83422	4.8698
	(2.60**)	(2.86**)	(2.19**)	(2.43**)

Source: Field survey, 2024. *** = 1 percent, ** = 5 percent and * = 10 percent level of significance respectively.

4.5. Impact of the FADAMA III Project on the Productivity of the Rice Farmers

The Chow's test was employed to examine the impact of the FADAMA III project on the productivity of rice farmers in the study area. This involved farmers who benefited from the project and those who did not. The results as presented in Table 7 show the significance of the tests for productivity effects, tests of homogeneity of slope and differences in intercept.

Table 7: Test for Difference in Productivity (Chow's test)

Nature of Analysis	Error Sum of Squares	Degree of Freedom	Calculated F
Tests for productivity effects			
Beneficiaries of FADAMA III	321.57	125	**14.25*****
Non-beneficiaries of FADAMA III	183.77	113	
Pooled data	535.55	239	
Tests of homogeneity of slope			
Beneficiaries of FADAMA III	321.57	125	**9.53*****
Non-beneficiaries of FADAMA III	183.77	113	
Pooled data with dummy	525.55	239	
Tests for differences in intercept			
Pooled data	535.55	239	**4.55*****
Pooled data with dummy	525.55	239	

Source: Field survey, 2024. *** = 1 percent level of significance

5. Discussion

5.1. Perception of the Respondents to Climate Change

The result as shown in Table 1 revealed that all the respondents across the various categories agreed that the mean temperature has increased in recent years. Also, irregular timing of seasons and salinity could result in a decrease in crop productivity with higher temperatures leading to an increase in diseases for humans, crops, and livestock, floods, droughts, and storms can cause damage to crops. This finding was in line with those of Bhuyan et al. (2024).

Longer droughts can lead to a reduction in crop output and that climate change can be caused by poor natural resource management (except for beneficiaries of FADAMA III project where 99 percent agreed). Apart from two responses - the dry season now arrives earlier than it did a decade ago and salinity intrusion has become more frequent in recent years than ten years ago where less than 86 percent agreed to have experienced climate change shifts, the respondents unanimously agreed that climate change effects negatively affected rice productivity. According to Uddin et al. (2014), while it is clear that these are perceptions of farmers, such information provides an important background of the respondent group.

5.2. Climate Change Adaptation Strategies of the Rice Farmers

5.2.1. Early Planting

The research findings revealed a striking trend where 94 percent of beneficiaries, 95 percent of non-beneficiaries, and 95 percent of the pooled respondents embraced early crop planting as a proactive measure to counteract the adverse effects of climate change. This widespread adoption of early planting underscored its perceived effectiveness in climate resilience strategies among both beneficiaries and non-beneficiaries alike. The finding aligned with those of Jirgi et al. (2019) whose findings revealed that it helped the rice farmers to reduce the effect of climate change while also generating more income at the end of the harvest year. Surprisingly, despite the FADAMA III programme's aim to enhance agricultural practices and resilience, the study unveiled that being a beneficiary did not notably influence the decision to adopt early planting as a climate change mitigation technique. This intriguing result suggested that factors beyond programme participation may play a more significant role in shaping farmers' adaptation behaviours, highlighting the complexity of agricultural decision-making in the face of climate variability.

5.2.2. Planting of Improved Varieties

Results from the research revealed that almost all the beneficiaries of the FADAMA III programme (99 percent), non-beneficiaries (96 percent) and pooled respondents (98 percent) reported that they planted improved varieties of rice. It is expected that being a beneficiary of a programmed aimed at increasing farmers' productivity should lead to a higher use of improved seedlings and varieties. However, since this programme has been in place for a period of time, other farmers who did not use the improved inputs in previous farming seasons, seeing the bumper harvest recorded by the initial beneficiaries and users of the improved variety would have been motivated to go for the improved varieties. The use of improved rice varieties was because they were resistant to harsh climatic conditions and this conforms with the findings of Kwasaki and Herath (2011), and Onyeneke (2021). From similar studies carried out in Benue state, Nigeria, by Arimi (2014), Idoma et al. (2017) and Jirgi et al. (2019), they reported that rice farmers in the state cultivated improved varieties as a means of mitigating the effect of climate change.

5.2.3. Minimum Tillage

In Ebonyi state, minimum tillage is not so much used in comparison to the other adaptation strategies. While more than half of the respondents (apart from the pooled respondents) across the groups practiced this strategy, it is pertinent to state that the terrain of the state does not support this practice. The soil in Ebonyi is stony and easily washed away by erosion, thus, farmers that practice it do so for dry season farming or a few upland rice farmers. However, the benefits of practicing minimum tillage as reported by Marenya et al. (2017) and Onyeneke (2021) include conservation of the environment, erosion management, improved soil fertility and farm yield as well as reduced climate change effect vulnerability of the farmers.

5.2.4. Drainage and Bund Construction

In light of the soil's limited capacity to retain water and its susceptibility to erosion, farmers in the study area adopted specific measures such as the construction of drainage systems and bund to mitigate the impacts from erosion. The data obtained indicated that a significant proportion of the rice farmers (86 percent of the beneficiaries, 79 percent of non-beneficiaries, and 83 percent of the pooled respondents), have implemented these techniques to combat erosion and manage water flow. This widespread adoption of drainage and bund construction underscores their perceived effectiveness as adaptive strategies in addressing the challenges posed by climate change-induced soil degradation. It also reflects the proactive approach taken by farmers, irrespective of their participation in specific agricultural support programmes, to safeguard their land and livelihoods against environmental threats.

5.2.5. The Combined Use of Organic and Inorganic Fertilizers

Utilizing a combination of organic and inorganic fertilizers emerged as a prudent approach across diverse soil types. Within the study area, an overwhelming majority of beneficiaries (94 percent), non-beneficiaries (91 percent), and pooled respondents (93 percent) embraced this strategy to mitigate the adverse impacts of climate change on rice cultivation. By adhering to best practices such as precise application in recommended quantities, sourcing organic and inorganic fertilizers from appropriate origins, and timing the application accurately, farmers bolster their resilience against climatic vagaries. This conscientious application does not only augment soil fertility but also contributes to environmental preservation, thereby fostering a symbiotic relationship between agricultural productivity and ecological sustainability (Dinesh and

Vermeulen, 2016; International Fertilizer Association, 2016; and Onyeneke, 2021). The widespread adoption of this method among rice farmers in Ebonyi State may be attributed to its demonstrable efficacy in navigating the challenges posed by shifting climatic patterns.

5.2.6. Crop Diversification/ Growing a Variety of Crops

All the beneficiaries (100 percent), 96 percent non-beneficiaries and 98 percent pooled respondents used crop diversification as a climate change adaptation strategy. The implication was that the rice farmers in the study area cultivated other crops alongside with rice, reinforcing the fact that mono-cropping is not a common practice in the study area. It is common for rice farmers in Sub-Saharan Africa to plant different crops on their farms as a way to manage risks and maximize the use of land. Tarfa et al. (2019) reported that this practice is a strategy against climate change effects especially in the Guinea Savanna area of Nigeria. This practice is important for moderating climate change through the effective spread of production and income risks which are incurred through planting single crops (FAO, 2018; Waha et al., 2018) and thereby reducing rice farmers' exposure to and vulnerability to climate shock.

5.2.7. Nursery Cultivation

The nature of rice makes it pertinent to plant it in nursery before transplanting to a larger site. However, the farmers did not give much attention to nursey cultivation as they did to other strategies. This probably could be because of the labour involved in transplanting and the fact that other strategies may be so effective in minimizing climate change effects. About 62 percent, 70 percent and 66 percent of the benefiting, non-benefiting and pooled respondents practiced nursery cultivation. According to Oselebe (2016), nursery is very important in rice production because of its role in enhancing germination and growth. Onyeneke (2021) further asserted that the reasons for adopting nursery cultivation is to guard against climate-associated risks which are more pronounced in the open field, especially at the early stages of the crop such as extreme temperature and flooding.

5.2.8. Adopting Water Conservation Practices

As reiterated, effective water management stands as a cornerstone for successful rice cultivation. The evidence can be seen with an impressive 96 percent of the respondents across all demographic groups engaging in such practices. These encompass a spectrum of strategies aimed at optimizing water usage and curbing environmental degradation. Among these techniques are the implementation of drainage systems, installation of erosion barriers, and the utilization of both dry and wet materials to combat soil erosion. By employing these methods, farmers not only ensure adequate water supply for their crops but also mitigate the risks associated with soil erosion, thereby safeguarding the long-term viability of their agricultural endeavours.

5.2.9. Adjustments in Planting and Harvesting Schedules

With almost all farmers agreeing that they adjusted their planting and harvest schedules to cope with climate change, it is evident that the practice is common. When the rains are delayed, farmers wait patiently before planting. In the Ebonyi State, where rains have been erratic in recent years, farmers cultivate their lands around March/April. Since there is no definite time the rain will come, they continue to wait, usually around May before they plant. Similarly, harvesting is also delayed due to changes in the dry seasons. Usually, certain crops are ready for harvest around August/September, but the changes in planting schedules implies that harvest is delayed until around October/November. This practice is inevitable following the changing pattern of rainfall (onset and cessation) and variability observed in sub-Saharan Africa (Choko et al., 2019; Onyeneke et al., 2017; Ezeh and Eze, 2016; Mbah and Ezeano, 2018; Gahatraj et al., 2018 and Tarfa et al., 2019).

5.2.10. Livelihood Diversification

Farmers in the study area also diversified their livelihoods into non-agricultural activities as a coping mechanism against changes in climate. By diversifying their livelihoods, they are free from the accompanying risks in agriculture such as floods, drought, erosion, pests and diseases and other unforeseen challenges. According to Onyeneke (2021), when rice farms are affected by climate change, the farmers depend on other sources of livelihood to cater for their families. The findings from his study corroborate that farmers in Africa have rich and sophisticated agro-ecological knowledge useful for climate adaptation. These adaptations are adjudged to be effective as households have relied on them to cope with the adverse impacts of the climate on rice production (Kim et al., 2017). The use of climate change adaptation strategies such as change in crop variety, change in size of farmland, early planting helped the rice farmers to reduce the effect of climate change, and this further translated into increased income. This implies that the adaptation measures utilized by the farmers were very effective and rice farmers in the study area relied on the strategies to cope with the adverse impacts of climate change on rice production.

Furthermore, the use of these adaptation strategies could enhance food security for farming households as well as reduce the huge foreign exchange expended on rice importation. This finding agrees with Mabe et al. (2012) who reported that farmers who had higher adaptive capacity had higher rice output and hence higher income.

5.3. Productivity Level of the Rice Farmers

5.3.1. Productivity Level of the Rice Farmers

The result of the analysis of the productivity levels of the rice farmers in the study area is presented in Table 3. This measures the total quantity of rice produced (kg/naira) to the cost of all inputs used (kg/naira). From the table, majority (62 percent, 82 percent, and 71 percent) of the FADAMA III beneficiaries, non-beneficiaries, and pooled sample rice farmers had productivity levels between 1.00 kg/naira and 10.0 kg/naira while about 36 percent, 18 percent, and 28 percent of the FADAMA III beneficiaries, non-beneficiaries and pooled sample rice farmers had productivity levels between 10.0 kg/naira and 19.99 kg/naira. Only about 2 percent of all the respondents had productivity levels between 20 kg/naira and 29.99 kg/naira. The analysis showed that a mean productivity level of 6.28 kg/naira, 5.60 kg/naira, and 6.28 kg/naira were achieved by beneficiaries, non-beneficiaries, and pooled rice farmers. Generally, the result showed that the rice farmers were productive in their rice farming activities (Mbam and Edeh, 2011). This is shown by the productivity level of the farmers which was greater than 1. The implication was that the rice farmers had higher returns from their investments in rice farming.

5.3.2. Determinants of Productivity of Rice Farmers in Ebonyi State

The results from the determinants of productivity for the rice farmers in Ebonyi State (as shown in Table 4) revealed that the coefficient of farm size was positive for the pooled farmers, beneficiaries, and non-beneficiaries at 1 percent, 10 percent and 1 percent levels of significance respectively. The implication was that farm size played a significant role in the productivity of farmers, that is, the larger the farms they had, the higher the levels of productivity they achieved.

To add to this, the coefficients of credit were positively related to the level of productivity of the farmers. This suggests that farmers who had access to credit achieved higher levels of productivity than farmers who did not have access to credit. Previous studies have shown that credit is very important in agriculture. This could be used in the purchase of farm inputs such as seedlings, fertilizer or in expenditures like the payment of labourers. Thus, farmers who have access to credit were able to purchase the inputs that were vital in increasing their productivity. This suggests that with sufficient capital available to bolster production, the output for rice was poised to expand significantly, accompanied by an increase in other essential inputs such as hired labour.

Bitrus et al. (2020) made emphasis on the pivotal role of credit in facilitating enterprise acquisition and development, asserting its profound impact on production capacity. Indeed, the availability of credit holds the potential to enhance farmers' productivity and uplift the livelihoods of rural farming communities facing economic disparities. Credit serves as a critical enabler, enabling farmers to invest in essential resources and technologies necessary for scaling up production. By providing access to financial resources, credit mechanisms empower farmers to optimize their operations, adopt innovative techniques, and overcome barriers to growth. Moreover, the infusion of credit into agricultural activities not only stimulates output expansion but also generates ripple effects that stimulate economic development within rural areas. Thus, the judicious utilization of credit holds promise as a catalyst for driving agricultural productivity gains and fostering socioeconomic advancement among marginalized farming communities. Thus, policies and initiatives aimed at improving credit accessibility stand to play a vital role in catalysing transformative change within the agricultural sector and beyond.

Extension contact was positively signed for the beneficiaries and non-beneficiaries of the project, implying that farmers who had contact with the extension agents experience higher productivity in rice production. Extension contact is essential to the improvement of farm productivity and efficiency among farmers. The primary objective of extension services is to empower farmers with the knowledge and skills necessary to optimize resource utilization, particularly in rice production, by transitioning away from traditional, less efficient methods. These outdated approaches often yield below normal results, contributing to low agricultural productivity (Bitrus et al., 2020). Establishing contact with extension agents play a pivotal role in this process, as these agents serve as conduits for disseminating vital information on the adoption of modern techniques and technologies, as well as the proper utilization of inputs such as fertilizers. Farmers who maintain regular communication with extension agents are better equipped to enhance their productivity levels. This enhanced performance can be attributed to the effective utilization of the knowledge and information imparted by these agents (Aymen et al., 2015; Cordelia and Edwin, 2020). By staying abreast of the latest agricultural innovations and best practices, farmers can make informed decisions that lead to improved efficiency and higher yields in rice production. In essence, extension services play a crucial role in bridging the gap between traditional and modern farming practices, thereby empowering farmers to achieve greater levels of productivity and sustainability.

5.3.2.1. Determinants of Productivity for FADAMA III benefitting Rice Farmers

The coefficient of labour input was negatively signed for pooled and nonbeneficiaries of the project at 1 percent level of significance. Labour cost is usually a leakage from the pull of resources such that farmers who spend much on labour, often experience a decline in productivity because the funds channelled into labour should have been used for other productive activities such as purchase of farm inputs. Thus, families with larger household sizes are better positioned to enjoy reduction in cost of labour because of the use of family labour and as such their farm productivity is enhanced. However, farmers with lower households or small family sizes do not enjoy this privilege of reduced investment in labour. Mbam and Edeh (2011) opined that an increase in the use of labour means incurring a higher cost of production, especially without an appreciable increase in output. This will certainly lead to a decline in productivity.

5.3.2.2. Determinants of Productivity for non–FADAMA III benefitting Rice Farmers

Similarly, the coefficient of capital input was negatively signed. Capital input involves expenses of items such as interest, depreciation of fixed items or cost and insurance. As this cost increases, productivity tends to decline because farmers may not be able to offset these costs as a result of their poor resource base. Inadvertently, such farmers usually experience a decline in their farm productivity as a result of increase in capital input. This is expected since costs are leakages from farmers stock of resources (Echebiri and Nwaogu, 2017).

The coefficient of the project use was positively signed. This variable is dummied one (1) representing farmers who benefited from the project and zero (0) representing farmers who did not benefit from the project. The positive coefficient implies that beneficiaries of the project had higher levels of productivity, therefore implying that the project increased the productivity level of the benefitting farmers.

5.4. Impact of FADAMA III Project on the Productivity of the Rice Farmers

This result therefore shows that there was a significant effect of the FADAMA III project on the rice farmers’ productivity. The productivity of the benefiting rice farmers were significantly higher than those of non-benefiting rice farmers in the study area. The implication is that FADAMA III project had a positive effect on the productivity of rice farmers in the study area. A similar study by Jirgi et al. (2019) reported that that rice farmers under the IFAD-VCDP had knowledge of various adaptation strategies and practiced them. Similarly, this could be attributed to the fact that a good number of the farmers under FADAMA III project have received trainings on climate change and ways of combating the menace.

6. Summary, Conclusions and Recommendations

6.1. Summary

The study was conducted to assess the climate change adaptation strategies of rice farmers in Ebonyi state, Nigeria. The specific objectives were to identify climate change adaptation strategies among the rice farmers; examine their productivity and productivity determinants and examine the impact of FADAMA III on the productivity of the rice farmers.

The multistage sampling techniques was used in the selection of FADAMA beneficiaries and non-beneficiaries in Ebonyi State. The kobocollect software, was used to design a well-structured questionnaire used to capture data on the objectives of the study. This method guaranteed that the data were correctly taken from the intended respondents without malpractices. Originally, a total of 120 beneficiaries and 120 non-beneficiaries of the FADAMA III project were to be selected but in practice, 124 beneficiaries and 116 non-beneficiaries were selected to have a total of 240 respondents for the study.

Data collected were analyzed using simple descriptive tools such as tables, charts, means, frequencies, and percentages as well as econometric tools such as Multiple regression, and the Chow's Test and from the findings, the result showed that all the respondents across the various categories agreed that the mean temperature has increased in recent years, irregular timing of seasons and salinity can result in a decrease in crop productivity, higher temperatures can lead to an increase in diseases for humans, crops, and livestock, floods, droughts, and storms can cause damage to crops, longer droughts can lead to a reduction in crop output and that climate change can be caused by poor natural resource management (except for beneficiaries of FADAMA III project where 99% agreed).

In a bid to minimize the adverse effects of climate change and variability on rice production in Ebonyi state, these farmers employed several strategies to cope with climate change. Notable among them are early planting, planting of improved varieties**,** the combined use of organic and inorganic fertilizers, adjustments in planting and harvesting schedules and livelihood diversification.

The result of the analysis of the productivity levels of the farmers measured in quantity of rice produced (kg) per naira cost of all inputs used that is, kg/N, showed that majority (62%, 82% and 71%) of the FADAMA III beneficiaries, non-beneficiaries and pooled sample rice farmers had productivity levels of between 1.00 kg/N and 10.0 kg/N while about 36%, 18% and 28% of the FADAMA III beneficiaries, non-beneficiaries and pooled sample rice farmers had productivity levels of between 10.0 kg/N and 19.99 kg/N.

To determine the factors affecting the productivity of rice farmers in Ebonyi state, the Multiple Regression Model was employed. Four functional forms of the Multiple Regression Model (Linear, Semi-log, Exponential, and Double log) were tested. The best fit was selected based on several econometric and statistical criteria such as number of significant variables, the value of the R^2, and signs and magnitude of the variables as they conform to economic theory. Based on these criteria, the double log functional form was selected as the best fit for the pooled farmers, whereas the exponential form was selected for the beneficiaries and non-beneficiaries of the FADAMA III project. The F-ratio was statistically significant at 1% indicating a high goodness of fit of the regression line.

The results showed that the coefficient of farm size was positive for the pooled farmers, beneficiaries, and non-beneficiaries at 1%, 10%, and 1% levels of significance respectively. The coefficients of credit were positively related to the level of productivity of the farmers. Extension contact was positively signed for the beneficiaries and non-beneficiaries of the project, implying that farmers who had contact with the extension agents experience higher productivity in rice production. The coefficient of labour input was negatively signed for pooled and nonbeneficiaries of the project at 1% level of significance. Similarly, the coefficient of capital input was negatively signed.

To examine the impact of FADAMA III project on the productivity of beneficiaries and non-beneficiaries rice farmers, the Chow test was employed, and the result showed that there was a significant effect of FADAMA III project on the rice farmers' productivity.

6.2. Conclusion

The study concludes that rice farmers in Ebonyi state perceived that climate change effect was real. They agreed that the mean temperature has increased in recent years, and that the irregular timing of seasons and salinity could result in a decrease in crop productivity with higher temperatures leading to an increase in diseases for humans, crops, and livestock, floods, droughts, and storms which could cause damage to crops. They also adopted climate change adaptation strategies such as early planting, planting of improved varieties, the combined use of organic and inorganic fertilizers, adjustments in planting and harvesting schedules and livelihood diversification. Farm size, credit, extension contact, labour input and capital input all influenced productivity while the Chow's Test concluded that there was a significant effect of FADAMA III project on the rice farmers' productivity.

6.3. Recommendations

Based on the findings of this study, the following recommendations are submitted:

1. Climate change adaptation strategies should be mainstreamed into agricultural policies, plans, and programmes designed to enhance agricultural productivity and profitability.

2. There is need for awareness campaigns by governmental and non-governmental organizations aimed at creating a knowledge base on the benefits of climate change adaptation strategies such as increased resilience to climate change effects and improved resilience.

3. Policies aimed at supporting climate change related infrastructures and such that ensure cost-effective access to agricultural inputs and subsidies for initial

investments, either through direct interventions or credit market support, should be pursued.

4. Credit must be made available to farmers to make investment on certain climate change adaptation strategies that are expensive. In addition, these credits could be in form of agricultural inputs made available at subsidized rates and at the appropriate times.

5. There is need for strong institutional will in the implementation of extension programmes aimed at educating farmers on effective climate change adaptation strategies.

6. Governmental prioritization of programmes aimed at improving farmers' productivity, such as the FADAMA programme, should be emphasized to support agricultural resilience in the face of climate change.

7. References

Abdoulaye T, Claessens L, Gumma MK, & Badiane O. 2018. Fadama-Based Irrigated Rice Production in Nigeria: Scaling Up a Successful Experiment.

Aderinoye-Abdulwahab SA. 2020. Agricultural policies and economic recovery and growth plan (ERGP 2017-2020), in Strategic Lenses: Economic Diversification and National Development in Nigeria, eds Kadiri MM, Attu EA, Alarape AL., Udeh CS. (Abuja: National Defence College, Abuja, Nigeria).

Akpokodje, G., Oboh, V., & Ejemot-Nwadiaro, R. (2012). Fadama II Project in Nigeria: Lessons and Experiences.

Arimi K. 2014. Determinants of climate change adaptation strategies used by rice farmers in South-Western Nigeria. Journal of Agriculture and Rural Development in the Tropics and Subtropics 115(2), 91-99.

Aryal JP, Rahut DB, Maharjan S, Erenstein O. 2018. Factors affecting the adoption of multiple climate-smart agricultural practices in the Indo-Gangetic Plains of India. *Natural Resources Forum* 42, 141–158.

Ayanlade A, Radeny M, Akin-Onigbinde AI. 2018. Climate variability/ change and attitude to adaptation technologies: a pilot study among selected rural farmers' communities in Nigeria. *GeoJournal*, 83, 319–331. DOI: 10.1007/s10708-017-9771-1

Aymen F, Boubaker D, Aw-Hassan A, Samia A, Ali I. 2015. Approaches to Total Factor Productivity Measurements in the Agriculture Economy, A CGIAR Research Program on Dryland Systems.

Barrett CB, Reardon T, Webb P. 2001. Nonfarm Income Diversification and Household Livelihood Strategies in Rural Africa: Concepts, Dynamics, and Policy Implications

Below T, Artner A, Siebert R, Sieber S. 2010. Micro-level practices to adapt to climate change for African small-scale farmers. *Rev. Sel. Lit*. 2010, 953, 1–20.

Bhuyan MI, Supit I, Kumar U, Mia S, Ludwig F. 2024. The significance of farmers' climate change and salinity perceptions for on-farm adaptation strategies in the south-central coast of Bangladesh. Journal of Agriculture and Food Research. Vol 16. 1 – 16. https://doi.org/10.1016/j.jafr.2024.101097 Bitrus A, Sulumbe IM, Ibrahim

A. 2020. Analysis of Rice Productivity among Beneficiaries of Anchor Borrowers Programme in Adamawa State, Nigeria: Data Envelopment Analysis Approach. *Asian Journal of Agricultural Extension, Economics & Sociology* 38 (11): 34-44, 2020.

Branca G, Tennigkeit T, Mann W, Lipper L. 2012. Identifying Opportunities for Climate-Smart Agriculture Investment in Africa; Food and Agriculture Organization of the United Nations: Rome, Italy, 2012.

Central Bank of Nigeria. 2016. 2016 Statistical Bulletin of the Central Bank of Nigeria, Abuja, Nigeria.

Choko OP, Olabisi LS, Onyeneke RU, Chiemela SN, Liverpool-Tasie LSO, Rivers IIIL. 2019. A resilience approach to community-scale climate adaptation. *Sustainability* 11, 3100.

Cordelia NO, Edwin O. 2020. Analysis of the factors influencing productivity of rice farms in Ebonyi State, Nigeria. *SVU-International Journal of Agricultural Science* Volume 2 Issue (2) pp.: 316-325, 2020 Print ISSN 2636-3801 | Online ISSN 2636-381X Doi: 10.21608/svuijas.2020.42033.1036

Dai A, Zhao T. 2017. Uncertainties in historical changes and future projections of drought. Part I: Estimates of historical drought changes. *Climatic Change*, 144, 519–533. DOI: 10.1007/s10584-016-1705-2.

Dinesh D, Vermeulen S. 2016. Climate change adaptation in agriculture: practices and technologies. Opportunities for climate action in agricultural systems CCAFS Info Note. Copenhagen, Denmark: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

Ezeh AN, Eze VA. 2016. Farm-level adaptation measures to climate change and constraints among arable crop farmers in Ebonyi state of Nigeria. *Agricultural Research Journal* 53, 492–500.

FAO. 2022. The State of World Food and Agriculture 2022: "Climate change is one of the biggest threats to food security and nutrition in the 21st century."

FAO. 2019. FAOSTAT.

FAO. 2018. Climate-Smart Agriculture: Crop Diversification Increases Productivity and Stabilizes Income of Smallholders. FAO Agricultural Development Economics, Policy Brief No 8. Rome, Italy: Food and Agriculture Organization.

Federal Ministry of Agriculture and Rural Development (FMARD). 2018. Unpublished document on Anchor Borrowers Programme Register for Ekiti State. FMARD Ekiti Area Office, Ado-Ekiti, Ekiti State. 77-184

Gahatraj S, Jha RK, Singh OP. 2018. Impacts of climate change on rice production and strategies for adaptation in Chitwan, Nepal. *Journal of Agriculture and Natural Resources* 1, 114–121.

Gandure S, Walker S, Botha J. 2013. Farmers' perceptions of adaptation to climate change and water stress in a South African rural community. *Environ. Dev*. 2013, 5, 39–53.

Ghile YB, Taner MÜ, Brown C, Grijsen JG, Talbi A. 2014. Bottom-up climate risk assessment of infrastructure investment in the Niger River Basin. *Climatic Change*, 122, 97–110. DOI: 10.1007/s10584-013- 1008-9.

Ghosh BC, Osmani MAG, Hossain ME. 2017. Perception of and adaption capacities to climate change adaption strategies by the rice farmers: A case of Rajshahi District in Bangladesh. *Perception* 2017, 3, 8–21.

Harvey CA, Rakotobe ZL, Rao NS, Dave R, Razafimahatratra H, Rabarijohn RH, Rajaofara H, Mackinnon JL. 2014. Extreme vulnerability of smallholder farmers to agricultural risks and climate change in Madagascar. *Philos. Trans. R. Soc. Lond. B Biol. Sci.*, 369(1639), 20130089. DOI: 10.1098/rstb.2013.0089.

Ho TT, & Shimada K. 2019. The effects of climate-smart agriculture and climate change adaptation on the technical efficiency of rice farming: an empirical study in the Mekong Delta of Vietnam. *Agriculture* 9, 99.

Idoma K, Ikpe E, Ejeh L, Mamman M. 2017. Farmers Adaptation Strategies to the Effect of Climate Variation on Rice Production: Insight from Benue State, Nigeria. Environment and Ecology Research 5(4), 289-301.

Intergovernmental Panel on Climate Change (IPCC). 2021. Sixth Assessment Report, 2021: "Fossil fuel combustion and industrial processes contributed about 78% of the total increase in anthropogenic greenhouse gas emissions from 1970 to 2011." (Chapter C2, Section 2.2.1)

International Fertilizer Association. 2016. The role of fertilizers in climate-smart agriculture: contribution of the International Fertilizer Association (IFA) to the UN Climate Change Conference in Marrakesh – COP22/CMP12.

Jirgi AJ, Oseghale AI, Aliyu MST, Tuedogheye JG, Jibrin S. 2019. Effect of climate change adaptation measures on the income of rice farmers under the IFAD-VCDP in Katcha Local Government Area, Niger State, Nigeria. African Journal of Agriculture Technology and Environment Vol. 8(1): 74-84 June, 2019. http://repository.futminna.edu.ng:8080/jspui/bitstream/123456789/6408/1/AJATE-Vol%208%20No%201%20%281%29.pdf

Kadiri FA, Eze CC, Orebiyi JS, Henri–Ukoha A. 2014. Economic Analysis of Paddy Rice Production in Niger Delta Region of Nigeria. *Asian Journal of Agriculture and Rural Development*, 4(12)2014: 541-550

Kawasaki J, Herath S. 2011. Impact Assessment of Climate Change on Rice Production in KhonKaeen Province, Thailand. ISSAAS Journal, 17 (2), 14–28.

Kim I, Ikpe E, Ejeh L, Mamman M. 2017. Farmers Adaptation Strategies to the Effect of Climate Variation on Rice Production: Insight from Benue State, Nigeria. *Environment and Ecology Research* 5(4): 289-301, 2017 DOI: 10.13189/eer.2017.050406

Kima AS, Traore S, Wang YM, Chung WG. 2014. Multi-genes programing and local scale regression for analysing rice yield response to climate factors using observed and downscaled data in Sahel. *Agricultural Water Management*, 146, 149–162. DOI: 10.1016/j.agwat.2014.08.007.

Knight J, Weir S, Woldehanna T. 2003. The Role of Education in Facilitating Risk-Taking and Innovation in Agriculture, The Journal of Development Studies, 39(6): 1-22.

Kurukulasuriya P, Mendelsohn R. 2007. A Ricardian Analysis of the Impact of Climate Change on African Cropland; The World Bank: Washington, DC, USA, 2007.

Lin JY. 1991, Education and Innovation Adoption in Agriculture: Evidence from Hybrid Rice in China, American Journal of Agricultural Economics, 73(3): 713-723.

Lu HP, Luo T, Fu HW, Wang L, Tan YY, Huang JZ, Shu QY. 2018. Resistance of rice to insect pests mediated by suppression of serotonin biosynthesis. *Nature Plants*, 4(6), 338- 344.

Mabe FN, Sarpong DB, Osei-Asare Y. 2012. Adaptive Capacities of Farmers to Climate Change Adaptation Strategies and their Effects on Rice Production in the Northern Region of Ghana. Russian Journal of Agricultural and Socio- Economic Sciences 11(11), 9-17.

Marenya PP, Kassie M, Jaleta M, Rahut DB, Erenstein O. 2017. Predicting minimum tillage adoption among smallholder farmers using micro-level and policy variables. *Agricultural and Food Economics* 5,

Mbah EN, Ezeano CI. 2018. Climate change adaptation measures practiced by rice farmers in Benue State, Nigeria. International Journal of Trend in Research and Development 3, 382–386.

Mbam BM, Edeh HO. 2011. Determinants of farm productivity among smallholder rice farmers in Anambra State, Nigeria. *Journal of Animal & Plant Sciences*, 9(3), 1187- 1191.

Mulenga BP, Wineman, A, Sitko NJ. 2017. Climate Trends and Farmers' Perceptions of Climate Change in Zambia. *Environmental Management*, 59, 291–306. DOI: 10.1007/s00267-016-0780-5.

National Bureau of Statistics. 2021. Nigerian Gross Domestic Product Report. National Bureau of Statistics, Abuja – Nigeria.

OECD. 2009. Integrating Climate Change Adaptation into Development Cooperation: Policy Guidance; Organisation for Economic Cooperation and Development: Paris, France, 2009. 22.

Okonofua JO, Isikwue BC. 2022. The impact of FADAMA IFAD projects on income diversification and food security in Edo State, Nigeria. International Journal of Sustainable Development, 25(2), 16-30.

Onyeneke RU, Amadi MU, Njoku CL. 2022. Climate change adaptation strategies by rice processors in Ebonyi State, Nigeria. *Ekológia (Bratislava)*, Vol. 41, No. 3, p. 283–290, 2022.

Onyeneke RU. 2021. Does climate change adaptation lead to increased productivity of rice production? Lessons from Ebonyi State, Nigeria. *Renewable Agriculture and Food Systems* 36, 54–68. https://doi.org/ 10.1017/S1742170519000486

Onyeneke RU, Igberi CO, Aligbe JO, Amadi MU. 2018. Prioritizing sustainable agricultural practices in a changing climate: empirical evidence from Ebonyi State of Nigeria. *International Journal of Agricultural Resources, Governance and Ecology* 14, 308–320.

Onyeneke RU, Mmagu CJ, Aligbe JO. 2017. Crop farmers' understanding of climate change and adaptation practices in southeast Nigeria. *World Review of Science, Technology and Sustainable Development* 13, 299–318.

Onyeneke RU. 2010. Climate Change and Crop Farmers' Adaptation Measures in the Southeast Rainforest Zone of Nigeria. Unpublished M.Sc. Thesis submitted to the Department of Agricultural Economics, Imo State University Owerri, Nigeria.

Oselebe HO, Nnamani CV, Efisue A, Onu D, Eze SO, Ogunji JO. 2016. Perceptions of climate change and variability, impacts and adaptation strategies by rice farmers in southeast Nigeria. *Our Nature* 14, 54–63.

Tarfa PY, Ayuba HK, Onyeneke RU, Idris N, Nwajiuba CA, Igberi CO. 2019. Climate change perception and adaptation in Nigeria's Guinea savanna: empirical evidence from farmers in Nasarawa State. Nigeria. *Applied Ecology and Environmental Research* 17, 7085–7112.

van Oort PAJ, Zwart SJ. 2018. Impacts of climate change on rice production in Africa and causes of simulated yield changes. *Global Change Biology*, 24(3), 1029–1045. DOI: 10.1111/gcb.13967.

Saheed Z, Alexander A, Isa A, Adeneye O. 2018. Anchor Borrower Programme on Agricultural Commodity Price and Employment Generation in Kebbi State, Nigeria. *European Scientific Journal,* 14(13): 213-256

Saito K, Dieng I, Toure AA, Somado EA, Wopereis MCS. 2015. Rice yield growth analysis for 24 African countries over 1960–2012. *Global Food Security*, 5, 62–69. DOI: 10.1016/j.gfs.2014.10.006.

Uddin MN, Bokelmann W, Entsminger JS. 2014. Factors Affecting Farmers' Adaptation Strategies to Environmental Degradation and Climate Change Effects: A Farm Level Study in Bangladesh. *Climate* 2014, 2, 223-241; doi:10.3390/cli2040223

UNDP. 2022. Human Development Report 2022: Uncertain Times, Unsettled Lives: Shaping Our Future in a Transforming World.

Waha K, van-Wijk MT, Fritz S, See L, Thornton PK, Wichern J, Herrero M. 2018. Agricultural diversification as an important strategy for achieving food security in Africa. *Global Change Biology* 24, 3390–3400.

Waller BE, Hoy CW, Henderson JL, Stinner B, Welty C. 1998. Matching Innovations with Potential Users: A Case Study of Potato IPM Practices, Agriculture Ecosystems and Environment, 70(2-3): 203-215.

Wheeler S, Zuo A, Bjornlund H. 2013. Farmers' climate change beliefs and adaptation strategies for a water scarce future in Australia. *Glob. Environ. Chang*. 2013, 23, 537–547.

Wheeler T, von Braun J. 2013. Climate Change Impacts on Global Food Security.\World Bank, World Development Report 2022: Finance for an Equitable Recovery

World Bank. 2013. Poverty in the Midst of Plenty. The challenge of growth in Nigeria. Report No. 14733 – United Nations, Pp. 45