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Climate Change Perception and Uptake of Climate-Smart Agriculture in Rice Production in Ebonyi State, Nigeria

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Abstract: Rice production in Nigeria is vulnerable to climate risks and rice farmers over time have experienced the risks and their respective impacts on rice farming. Rice farmers have also responded to perceived climate risks with strategies believed to be climate-smart. Farmers' perception of climate risks is an important first step of determining any action to be taken to counteract the negative effects of climate change on agriculture. Studies on the link between perceived climate risks and farmers' response strategies are increasing. However, there are limited studies on the determinants of rice farmers' perception of climate events. The paper therefore examined climate change perception and uptake of climate-smart agriculture in rice production in Ebonyi State, Nigeria using cross-sectional data from 347 rice farmers in an important rice-producing area in Nigeria. Principal component analysis, multivariate probit regression model and descriptive statistics were adopted for data analysis. Perceived climate events include increased rainfall intensity, prolonged dry seasons, frequent floods, rising temperature, severe windstorms, unpredictable rainfall pattern and distribution, late onset rain, and early cessation of rain. Farmers' socioeconomic, farm and institutional characteristics influenced their perception of climate change. Additionally, rice farmers used a variety of climate-smart practices and technologies to respond to the perceived climate events. Such climate-smart practices include planting improved rice varieties, insurance, planting different crops, livelihood diversification, soil and water conservation techniques, adjusting planting and harvesting dates, irrigation, reliance on climate information and forecasts, planting on the nursery, appropriate application of fertilizer and efficient and effective use of pesticides. These climate-smart agricultural measures were further delineated into five broad packages using principal component analysis. These packages include crop and land management practices, climate-based services and irrigation, livelihood diversification and soil fertility management, efficient and effective use of pesticide and planting on the nursery. High fertilizer costs, lack of access to inputs, insufficient land, insufficient capital, pests and diseases, floods, scorching sun, high labour cost, insufficient climate information, and poor extension services were the barriers to uptake of climate-smart agriculture in rice production. Rice farmers should be supported to implement climate-smart agriculture in rice production in order to achieve the objectives of increased rice productivity and income, food security, climate resilience and mitigation.

Keywords: climate change; perception; rice farming; climate-smart agriculture; principal component analysis; multivariate probit regression; constraints



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1. Introduction

As the climate changes, it affects different aspects of the environment. Droughts, strong windstorms, floods, unpredictable rainfall volume, rising temperatures, late and early rain start, and other negative effects of climate change witnessed in previous years are becoming more common presently [1]. As the earth heats, rainfall patterns tend to vary, and extreme events such as droughts, floods, and forest fires become more common and severe [2]. Climate change could also result in more pressure on water bodies [3,4].

Climate change is one of the most serious challenges to Africa's agricultural sector and food security due to its sensitivity and vulnerability to temperature and rainfall changes [5]. Higher temperatures, for example, reduce crop yields while increasing incidence of pests, and variations in precipitation patterns raise the risk of short-term crop failure and long-term output losses, making climate change a major problem to food production [1]. Climate change has become a big problem all over the world, particularly as it relates to agriculture. This is because climate change is considered as negatively affecting agricultural development, food security, and man's overall livelihood situation [6]. Farming operations, particularly those that are rainfed, rely on good climatic conditions to be productive and are in danger as a result of climate change [5].

Crop production is at the mercy of changing climate, which could affect rice production depending on the severity of climate change [7]. Rice is one of the most important cereal crops for feeding the world's rising population [8]. Rice is also a major food crop in sub-Saharan because it has become a substantial source of calories to the diets of the inhabitants of the region [9]. Rice output in Nigeria, in general, will need to expand in order to meet future population growth. Any decrease in rice yield as a result of climate change would jeopardize the food security efforts of Africa's most populous country. Describing the effects of climate change on rice production and measuring rice farmers' ability to respond to climate change are therefore critical research subjects. Ebonyi State is an important rice-producing area in Africa's most populous country (Nigeria). A significant proportion of the population depends on rice farming, which is their primary source of food and farm income for survival [10]. Despite the importance of rice to Ebonyi State's rural economy, climate change is threatening its productivity and output. Climate change is expected to have some of the most dramatic and immediate effects on agriculture and food systems in the coming decades [11]. Climate is changing rapidly, and its related hazards have been variously perceived by farmers [12]. Some authors have defined climate perception to mean a complex process encompassing knowledge and beliefs about how climate change is happening [13,14]. Other factors such as farmers' characteristics, information and institutional characteristics, location, and culture also shape climate change perception [12–15]. Perceptions of those whose livelihood activities depend largely on climate (especially rice farmers) are often times accurate [14] and this informs the choices farmers make in responding to the perceived climate risks. This is why it is important to explore farmers' perceptions on climate change, factors shaping perception, and uptake of strategies to respond to climate risks.

Climate change perception by crop farmers is an important step for determining any climate risk management and mitigation measure [16–18]. Response to climate change is usually a two-step process, which include perceiving climate change/event and based on the perceived event take appropriate measures to manage the risks associated with the event. Studies have also matched farmers' perception of climate events with scientific data from meteorological institutions/stations to ascertain the convergence or divergence of scientific data with local/anecdotal accounts [17–19]. These studies generally show that farmers' perception of climate events were always in line with meteorological data analysis, which further justifies the need to study farmers' perception of climate events as an important first step to responding to climate change.

There is a need to translate the perception of the farmers and the drivers of such perceptions into quick positive actions to manage the negative effects of climate change. One such important action to respond to perceived climate events by farmers is climate-smart agriculture. Climate-smart agriculture entails the adoption/use of technologies/techniques/practices/services to simultaneously increase crop yield, climate resilience and mitigation and food security [20,21]. This is quite different from conventional agriculture which usually increases emissions and is less resilient to climate risks.

Rice production is a significant contributor to greenhouse gas emissions in Ebonyi State and many other parts of Nigeria [22,23]. The recently submitted Nigeria's Nationally Determined Contribution, the First Biennial Update Review and the Third National

Communications noted the significant contributions of rice production to greenhouse gas emissions in the country [22–24]. One important mitigation measure to reduce greenhouse gas emissions in Nigeria is the adoption of climate-smart agriculture especially in rice production [24]. This makes the study of climate-smart agriculture in rice production in important rice-producing ecologies in sub-Saharan Africa, such as Ebonyi State, very important. Interest in this issue is one of the motivations of this study.

It is clear from the foregoing that rice farming is a major contributor to climate change and a major sufferer of the impacts of climate change. Analysis revealed that climate change will have a negative impact on Nigeria's food security, prompting the implementation of various climate change adaptation and mitigation measures [25]. Responses that sustainably and simultaneously reduce the impacts of climate change on rice production, increase rice productivity and reduce/avoid/remove above and below ground carbon emissions are needed. Such responses are known as climate-smart agricultural practices, technologies or services and they are location and context-specific [26–29]. There is great potential to boost food production, increase resilience and carbon mitigation via large-scale adoption of climate-smart agriculture in rice farming. The adoption of climate-smart agriculture in rice production has the potential to increase income, food security and improve diets in Nigeria [24]. Conversely, climate-smart agriculture in Nigeria is at the nascent stage and its adoption in rice production is still low in the country [21,30]. Policy-makers require understanding of climate change perception and uptake of climate-smart agricultural practices in rice production in Nigeria to be able to meet the country's obligation of reporting progress made in the implementation of the Nationally Determined Contribution. Additionally, knowledge of the climate-smart agricultural practices in rice production will help the government to address the challenges facing farmers in adopting climate-smart agricultural technologies in the State and other locations with similar socioeconomic and biophysical contexts in Africa. Again, knowledge of the perception of climate change and its determinants will further trigger policies to drive down positive climate change response mechanisms in Nigeria and sub-Saharan Africa.

The study was therefore conducted to determine climate change perception and uptake of climate-smart agriculture in rice production in an important rice-producing State in Africa. This study also contributes to the literature on climate-smart agriculture in rice production by applying the principal component analysis to categorize climate-smart agricultural strategies used by rice farmers in an important rice-producing State in Nigeria.

2. Methodology

2.1. Sampling and Data Collection

The paper relied on a survey of rice farmers conducted in nine Local Government Areas in Ebonyi State, Nigeria between October 2019 and February 2020. The State has three zones. We included all the zones of the State in this study because rice is grown in all Local Government Areas of the State. In each zone, three Local Government Areas (LGAs) were purposively selected based on the degree of rice production ranked by officials of the Agricultural Development Programme in the State. The selected LGAs in each zone are shown in Figure 1. In each LGA, four communities were selected. In each community, the study selected ten rice farmers. During data entry and analysis, we observed that thirteen (13) returned questionnaires were not properly completed by the farmers. These questionnaires were not included in the final analysis. This reduced the number of observations from 360 rice farmers proposed to 347 farmers.

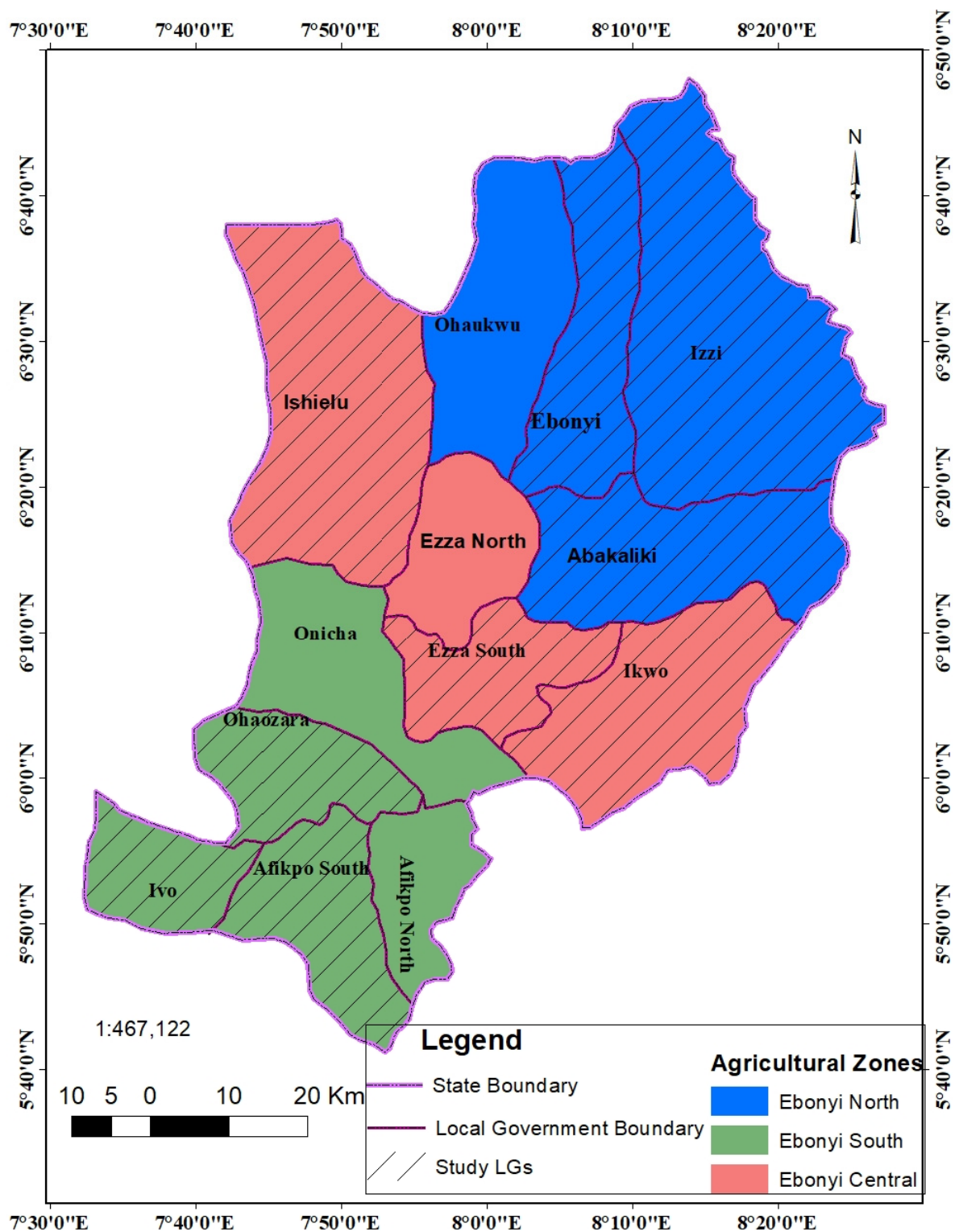


Figure 1. Map of Ebonyi State showing the LGAs.

We collected data on socio-economic, farm and institutional characteristics of the rice farmers, rice farmers' perception/experience of climate events. We also collected data on climate-smart practices and technologies used in rice production and the constraints to uptake of such practices and technologies.

2.2. Data Analysis

The paper used descriptive statistics, principal component analysis and multivariate probit regression model to analyse the data collected. We used descriptive statistics to describe the characteristics of farmers, highlight farmers' perception on climate change and ascertain the barriers to uptake of climate-smart agricultural practices and technologies in rice production. To categorize the uptake of different individual climate-smart agricultural practices and technologies in rice production, we used the principal component analysis. We grouped the practices/technologies into heterogeneous clusters by the use of principal component analysis (PCA). The PCA has also been used in the literature to group climate risk management measures [31,32]. The practices were grouped using PCA with iteration and varimax rotation in the model shown below:

$$\begin{aligned} Y_1 &= a_{11}x_{12} + a_{12}x_2 + \dots + a_{1n}x_n \\ Y_g &= a_{g1}x_{g1} + a_{g2}x_2 + \dots + a_{gn}x_n \end{aligned} \quad (1)$$

where; Y_1, \dots, Y_g represent the principal components, which are uncorrelated. a_{11}, \dots, a_{gn} represent the correlation coefficients. x_1, \dots, x_n represent the climate-smart agricultural strategies. We used the SPSS to carry out the principal component analysis.

We also modelled the determinants of farmers' perception of climate events. The literature is replete on farmers' perception of climate change but there is scanty empirical evidence on the determinants of farmers' perception of climate events. Farmers perceive different climate events and the events are usually interrelated. Available literature in sub-Saharan Africa has largely treated the determinants of perception singly see [16,33–38] without due consideration to the interrelated nature of perceived climate events. Although we are aware of the study of Liverpool-Tasie et al. [12], an exception in Nigeria, that considered the interrelated nature of farmers perceived climate events, the study however dealt with maize and poultry farmers. Rice farming is a significant contributor to greenhouse gas emissions in Africa's most populous country (Nigeria) and mitigation through adoption of climate-smart agricultural practices is needed to meet Nigeria's obligation to the global community as contained in the Nationally Determined Contribution [24]. It makes scientific and economic sense to consider the determinants of rice farmers' perception of climate change and how interrelated the perceived climate events are for effective programmes on climate change resilience and mitigation in the country and other countries with similar contexts. We therefore explored the determinants of climate change perception in rice farming using the multivariate probit model. The multivariate probit regression model treats the effects of predictors on various simultaneously perceived climate events and ensures that the disturbance terms of each perceived event is freely correlated. This model accounts for the interdependent nature of the perceived climate events and inform scientists whether the perceived events are complements or substitutes. The MVP further explains the potential relationship between climate change perception and unobserved factors [39]. Therefore, the multivariate probit (MVP) model has a set of dichotomous dependent variables (P_i) such that:

$$\begin{aligned} P_i^* &= \beta_i'X_i + u_i = 1, \dots, I \\ P_i &= \begin{cases} 1 & \text{if } P_i^* > 0 \\ 0 & \end{cases} \end{aligned} \quad (2)$$

where; β_i' represents the vector of parameter estimates, and P_i^* denotes the latent variable. Equation (2) assumes that a rice farmer has a latent variable, P_i^* , that considers unobserved factors related to the n th perceived climate event. P_i^* is a linear combination of household socioeconomic characteristics, household assets, farm and institutional characteristics (X_i) affecting the simultaneous perception of climate events, as well as the unobserved factors explained by the error term u_i . P_i indicates the dependent variables measured whether or not a rice farming household has perceived a particular climate event.

The dependent variables are the perceived climate events and they are listed below:

P_1 = Perceived increased rainfall intensity (Yes = 1, No = 0)

P_2 = Perceived prolonged dry season (Yes = 1, No = 0)

P_3 = Perceived frequent floods (Yes = 1, No = 0)

P_4 = Perceived increased temperature (Yes = 1, No = 0)

P_5 = Perceived severe windstorm (Yes = 1, No = 0)

P_6 = Perceived unpredictable rainfall volume (Yes = 1, No = 0)

P_7 = Perceived late onset of rain (Yes = 1, No = 0)

P_8 = Perceived early cessation of rain (Yes = 1, No = 0)

X_i represents the vector of independent variables. The independent variables are listed below:

X_1 = Education (Years spent in school)

X_2 = Age (Years)

X_3 = Household Size (Number of persons)

X_4 = Off-farm employment (Yes = 1, No = 0)

X_5 = Gender (Male = 1, Female = 0)

X_6 = Extension contact (Number of visits per year)

X_7 = Access to credit (Naira)

X_8 = Ownership of television (Yes = 1, No = 0)

X_9 = Ownership of mobile phone (Yes = 1, No = 0)

X_{10} = Ownership of radio (Yes = 1, No = 0)

X_{11} = Membership of farmer groups (Yes = 1, No = 0)

X_{12} = Training on CC and/or rice farming (Number of times per year)

X_{13} = Marital status (Married = 1, Single = 0)

X_{14} = Reliance on government support (Yes = 1, No = 0)

X_{15} = Farm size (Hectare)

X_{16} = Income (Naira)

The choice of the independent variables was supported by available literature on factors influencing climate change perception in sub-Saharan Africa [12,16,33–38]. We used the STATA software to carry out the multivariate probit regression analysis.

3. Results and Discussion

3.1. Socio-Economic Characteristics of the Farmers

Table 1 showed the socio-economic characteristics of the farmers in the area. From the Table, the mean number of years spent in school was 9 years, implying that the farmers in the area at least had junior secondary education. Education is seen as a very veritable tool in this era of climate change because it helps farmers to access practices and technologies for responding to climate change. By this, farmers are able to properly withstand the adverse effects of climate change affecting rice production in the area [21]. Mean age of the farmers was 46 years. This implies that rice farmers in the area were young and in their prime age which avails them more opportunity to access climate information regarding the rice farming business. Age is notably an important factor in agriculture as it determines to a great extent the productivity of the farmers in general [10]. The mean household size was approximately 7 persons, which implies that the rice farmers had a relatively large household size which some of them could be relatives, extended dependents, etc. which undoubtedly could assist in rice production and in responding to the changing climate in the area. This is also related to the findings of Abegunde et al. [40] and Mujeyi et al. [41]. The majority (65%) of the farmers were males. This implies that there were more male farmers than female farmers in rice production. Africa is more of a patriarchal society, which allows men to access and own agricultural inputs such as (lands, credit facilities, improved seedlings, etc.) more easily than women [42]. Additionally, male farmers are able to withstand the negative impacts of climate change and access climate information more than female farmers. The extension values of 0.57 (57%) and 3.31 showed that about 57 percent of the rice farmers accessed extension services and were visited at least 3 times per year by the extension agents. Anugwa et al. [30] also found a similar

level of extension access among rice farmers in another location in Nigeria. Extension services have a way of exposing farmers to new and recent knowledge on rice farming via the introduction of innovative technologies and updated climate information which empower the farmers to respond to climate change. Furthermore, extension visits build strong resilience amongst farmers in adapting to the adverse impacts of climate change [10]. The mean farming experience was 13.08 years. This means that rice farmers in the area have quite enough years to gather practical knowledge to solve inherent rice cultivation problems and be able to overcome both internal and external challenges affecting rice production. It is widely believed that the more experienced a farmer is the more likely the farmer would be in overcoming climate risks and implementation of long acquired practical knowledge [43] to boost rice production. About 28% of the farmers had access to credit. This implies that a small proportion of the rice farmers were able to access credit facilities from formal and informal sources. Generally, access to credit empowers rice farmers to acquire more agricultural inputs such as lands, fertilizers, improved seedlings, etc. [44]. However, access to credit could equally trigger access to climate information, since a farmer is privileged to move about in search of credit facilities, he/she may equally come across a discussion on climate change and what it offers, which could be efficiently and effectively utilized. It is interesting to note that 71%, 91% and 80% of the farmers had television, mobile phone and radio, respectively. These assets enhance both reception and communication of climate information, which help the farmers in overcoming adverse effects of climate change on agricultural production [45]. Similarly, 19 percent had at least a car, 67 percent had at least a motorcycle, 8 percent had at least a tricycle and 42 percent owned at least one bicycle. These means of transportation enhance both the movement of the rice farmers and their produce from the point of production to the point of sale as well as the movement of inputs (including climate-smart agricultural technologies) from point of purchase to the farm. Access to transportation is also a major determinant in the marketing of agricultural produce as it enhances free movement of goods and services between the rural and urban markets without many restrictions [46]. Furthermore, the result showed that about 53 percent of the rice farmers were members of farmer groups/associations. This implies that through the association, rice farmers could access both climate information and other agricultural inputs (including climate-smart agricultural technologies). Membership of farmers' associations encourages the transference of diverse knowledge and farm requisite information which help farmers in responding to climate change as well as boosting farm production [47]. Again, about 40 percent of the rice farmers attended trainings/workshops on climate change and/or rice farming and the average number of trainings/workshops attended per year was 1.52. This implies that the rice farmers were able to access vital information on rice farming and also on climate change via their attendance. These trainings and workshops have a way of communicating vital information which ordinarily is beyond the reach of farmers [48]. Through these trainings and workshops, farmers meet and interact with other farmers from various regions and locations. This could possibly serve as a medium of communicating other recent agricultural information/innovations. Eleven percent of rice farmers rely on government support in counteracting the negative impacts of climate events. The mean farm size of the rice farmers in the area was 1.47 hectares, this is typical of rural farmlands which are usually small in size, disjointed and fragmented [49,50]. This size of farmland could hardly support commercial farm production.

Table 1. Socio-economic characteristics of farmers.

Variable	Mean/Percentage
Education (years spent in school)	8.65
Age (years)	46.06
Household size (number of persons)	6.55
Gender (percentage of male)	0.65
Extension contact (percentage of access)	0.57
No of extension visits (number of visits per season)	3.31
Farming experience (years)	13.08
Access to credit (percentage of access)	0.28
Ownership of television (percentage having television)	0.71
Ownership of mobile phone (percentage having phone)	0.91
Ownership of radio (percentage having radio)	0.80
Ownership of car (percentage having car)	0.19
Ownership of motorcycle (percentage having motor cycle)	0.67
Ownership of tricycle (percentage having tricycle)	0.08
Ownership of bicycle (percentage having bicycle)	0.42
Membership of farmer groups (percentage of members)	0.53
Workshop/training on CC and/or rice farming (percentage received training or workshop)	0.40
Number of times participated in such workshops/trainings (number of times participated in a season)	1.52
Rely on government support (percentage relied on government for support)	0.11
Farm size (ha)	1.47

3.2. Farmers' Perception of Climate Events

Figure 2 showed the perceived climate events in the area. Increased temperature was perceived by over 90 percent of the rice farmers as a major climate risk affecting rice production in the area. Rice reproductive and developmental stages are hampered by high temperature, which reduces yield [51,52]. Increased rainfall intensity was cited by nearly 90% of rice producers as a perceived climate change concern. It is undeniable that higher rainfall intensity has an impact on rice production, resulting in lower yields and inferior grains [53]. Increased rainfall intensity causes erosion, which can destroy rice fields and rice grains. Erosion can take vital plant-available nutrients and organic matter with it when soil is lost. Flooding can also occur as a result of increased rainfall intensity, reducing outputs and exacerbating the local food security situation [54]. Flood deposits may raise nitrogen, phosphorous, silicon, and potassium levels in the soil, resulting in nutrient surpluses that can stymie rice development [55]. Crop loss, soil erosion, and increased flooding owing to heavy rains are all potential consequences of high precipitation, which can impact agricultural output. Approximately 83.3 percent of rice farmers viewed prolonged dry season as a serious climate event. Long dry seasons could reduce soil moisture content [56], denying planted grains access to the moisture they need for growth and crop development. Drought could be triggered by a protracted dry season, causing considerable harm to rice crops, especially if it occurs during critical times of crop development, such as after planting or flowering [57]. Drought can limit agricultural growth, resulting in lower yields and lower quality produce. Approximately eighty-two percent of the rice farmers believed that the area is prone to flooding. Rice (paddy) can be farmed in swamp (flood) locations, but regular flooding of farmlands washes away the fertile topsoil, leaving the soil less fertile. Flood water can suffocate and kill crops by depositing sand and debris. Crops can be damaged and output losses can occur even after floodwaters have receded. Flood does not only lower plant defences, but the soil and water conditions that prevail during flooding also favour the development of many plant diseases, resulting in an increase in the incidence of crop diseases [58]. Additionally, water in the soil or above the soil surface means that plants have less oxygen available to them, and one effect of low oxygen is a drastic reduction in metabolism, which can dramatically reduce yield and, if prolonged enough, cause death to a portion or the entire plant. Flooding has the potential to alter the amount of plant-available nutrients in the soil. The climate events

perceived/experienced by rice farmers in Ebonyi State—unpredictable rainfall pattern and distribution, increased rainfall intensity, prolonged dry season, frequent floods, increased temperature, severe windstorm, late onset of rain and early cessation of rain—are all in line with meteorological/scientific data analyses conducted in previous studies in Ebonyi State and Nigeria [10,59,60].

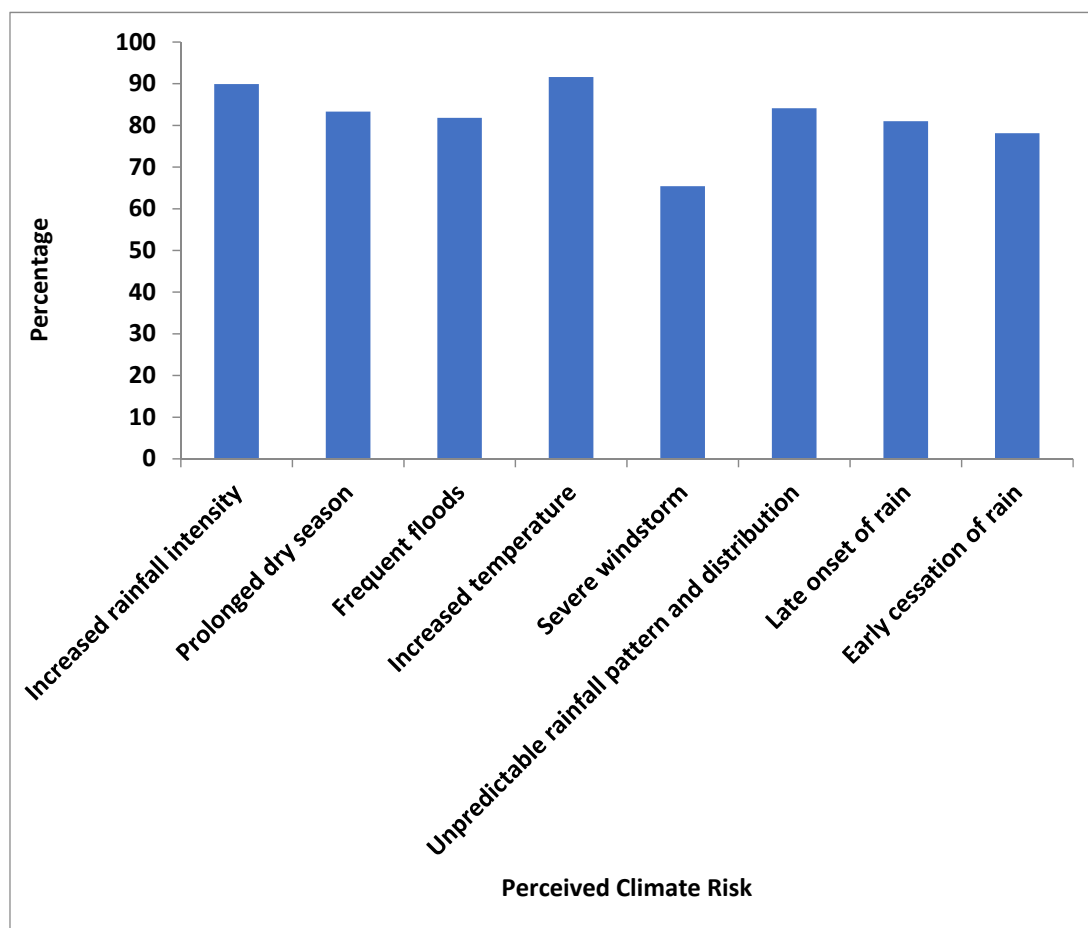


Figure 2. Farmers' perception of climate events.

Unpredictable rainfall pattern and distribution was cited by more than 83 percent of rice farmers as one of the climate change threats affecting rice output in the area. Farmers find it extremely difficult to plan their farming operations due to the unpredictable rainfall pattern and distribution, as they are frequently stuck (confused) on how to go about their rice cultivation [61,62]. Rainfall unpredictability is a major climate change event affecting agriculture [54,62,63]. Rain-fed rice, on the other hand, is primarily impacted by shifting rainfall patterns and rising temperatures. Extreme climate events such as floods and droughts are triggered by this irregular rainfall pattern and distribution, which have a negative impact on rice crops. Rainfall has a significant impact on soil. Nutrients in the soil can flow off and not reach the roots of plants if the weather is too wet or too dry, resulting in poor development and overall health of the planted crops. About 65% of rice growers reported experiencing a severe windstorm. Severe windstorms may induce a significant impact on rice production by inflicting severe damage and causing fractures, bends, and other sorts of injuries that result in reduced productivity. Heavy wind disrupts the growth and balance of planted crops, causing major damage. Severe windstorms can cause entire crop failure as well as soil surface erosion. Similarly, 81% and 78.1% of rice farmers have perceived late commencement and early cessation of rain as significant climate change threats to rice productivity. Late rains disrupt farmers' planting

schedules, causing extended delays in rice farming, particularly highland rice cultivation, and resulting in low yields or product [64]. This prolongs the time it takes for farmers to begin cultivating their land. Early cessation of rainfall produces land dryness (drought) in the planted grains, resulting in immediate crop mortality. Furthermore, early rainfall cessation can cause poor soil aeration and lower moisture root content, resulting in poor crop growth and yields [58].

3.3. Determinants of Farmers' Perception of Climate Events

Table 2 showed the multivariate probit result of determinants of farmers' perception of climate events in the area. The Wald likelihood ratio Chi-square value of 202.69 was significant at 1 percent probability level, showing that the multivariate probit (MVP) regression model fitted appropriately in estimating the determinants of farmers' perception of climate events in the area.

Table 2. Multivariate probit regression result of determinants of farmers' perception of climate events.

Variables	Increased Rainfall Intensity	Prolonged Dry Season	Frequent Floods	Increased Temperature	Severe Windstorm	Unpredictable Rainfall Pattern and Distribution	Late Onset of Rain	Early Cessation of Rain
X ₁ (Education)	−0.036 (−1.53)	0.010 (0.48)	−0.114 (−5.33) ***	0.002 (0.09)	−0.054 (−3.13) ***	−0.009 (−0.44)	0.042 (2.07) **	0.040 (2.17) **
X ₂ (Age)	0.009 (0.74)	−0.013 (−1.23)	−0.029 (2.71) ***	0.018 (1.29)	−0.029 (−3.26) ***	−0.013 (−1.35)	−0.023 (−2.43) **	−0.026 (−2.77) ***
X ₃ (Household size)	−0.015 (−0.47)	0.042 (1.44)	−0.047 (−1.71) *	−0.034 (−0.97)	0.003 (0.15)	0.018 (0.65)	0.078 (2.91) ***	0.011 (0.43)
X ₄ (Off-farm employment)	−0.182 (−0.79)	0.282 (1.48)	−0.156 (−0.78)	−0.095 (−0.39)	0.203 (1.23)	0.017 (0.09)	0.231 (1.30)	0.337 (1.95) *
X ₅ (Gender)	−0.015 (−0.07)	−0.379 (−1.94) *	0.065 (0.35)	−0.418 (−1.68) *	−0.164 (−1.03)	0.027 (0.16)	−0.134 (−0.79)	−0.088 (−0.55)
X ₆ (Extension)	0.014 (0.045)	−0.024 (−0.88)	0.026 (0.95)	−0.050 (−1.63)	−0.028 (−1.30)	0.037 (1.27)	−0.035 (−1.39)	−0.024 (−0.99)
X ₇ (Credit)	-7.29×10^{-7} (−0.57)	1.72×10^{-6} (1.24)	9.95×10^{-7} (0.81)	-9.62×10^{-7} (0.67)	0.56×10^{-6} (1.44)	1.10×10^{-6} (0.88)	1.04×10^{-6} (0.82)	8.87×10^{-7} (0.69)
X ₈ (Television)	−0.015 (−0.06)	−0.354 (−1.54)	−0.141 (−0.61)	0.246 (0.95)	0.015 (0.08)	−0.187 (−0.90)	−0.641 (−3.11) ***	−0.152 (−0.79)
X ₉ (Phone)	0.200 (0.55)	−0.963 (−2.04)	0.098 (0.28)	−0.618 (−1.28)	−0.079 (−0.28)	−0.594 (−1.61)	−0.581 (−1.74) *	−0.156 (−0.56)
X ₁₀ (Radio)	−0.152 (−0.56)	0.053 (0.22)	−0.207 (−0.83)	0.374 (1.46)	0.116 (0.57)	0.111 (0.52)	0.120 (0.54)	−0.040 (−0.19)
X ₁₁ (Farmer group)	−0.037 (−0.15)	0.500 (2.13) **	0.251 (1.12)	0.314 (1.11)	0.010 (0.06)	0.136 (0.65)	0.071 (0.34)	−0.027 (−0.13)
X ₁₂ (Workshop/Training)	0.027 (0.52)	−0.037 (−0.76)	0.057 (1.27)	−0.015 (−0.28)	0.032 (0.86)	−0.013 (−0.28)	0.034 (0.76)	0.047 (1.04)
X ₁₃ (Marital Status)	0.380 (1.33)	0.481 (1.80) *	0.213 (0.80)	0.081 (0.23)	0.151 (0.63)	0.524 (2.11) **	0.247 (0.90)	0.287 (1.10)
X ₁₄ (Government Support)	−0.042 (−0.13)	0.299 (0.98)	−0.069 (−0.23)	0.618 (1.41)	0.381 (1.49)	−0.174 (−0.67)	−0.098 (−0.39)	−0.292 (−1.22)
X ₁₅ (Farm Size)	0.004 (0.04)	−0.005 (−0.06)	−0.108 (−1.33)	0.051 (0.37)	−0.114 (−1.62)	0.014 (0.18)	0.00008 (0.01)	−0.045 (−0.60)
X ₁₆ (Income)	4.15×10^{-7} (0.26)	1.51×10^{-7} (0.15)	1.38×10^{-7} (0.12)	9.90×10^{-7} (0.52)	2.26×10^{-7} (0.24)	1.56×10^{-6} (1.23)	1.67×10^{-6} (1.48)	3.81×10^{-7} (0.37)
Wald chi ² (128)	202.69 ***							

Note: values in parenthesis are z-values. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

Educational attainment of the farmers had a significant negative relationship with frequent floods, severe windstorms and a positive significant relationship with late onset of rain and early cessation of rain. The implication is that educated people are more enthusiastic to note the changes in climate more than uneducated people. Educated people become very conscious about their environment and sense the changes in climate

better [65]. This further implies that education influences farmers' perception of climate events. An increase in educational attainment of the farmers increases their perception, understanding and knowledge base in handling climate events such as late onset of rain and early cessation of rain. Education is notably a key determinant aimed at assisting the farmers to overcome the horrible experiences of climate events such as late onset of rain and early cessation of rain [38]. It has a way of equipping the farmers with the right knowledge and relevant information cum exposure in handling the challenges of late onset of rain and early cessation of rain which regularly interfere with the planting calendar. With this knowledge, farmers are in a better position to utilise the climate change information services to their advantage without many limitations.

The age of the farmers was negatively related to frequent floods, severe windstorms, late onset of rain, and early cessation of rain. This generally implies that younger farmers perceived more of these hazards than older farmers. This could be true because younger farmers are more involved in agriculture and other natural resource-dependent activities than the older ones and more likely to notice any changes in climate. Young farmers respond easily to trainings, workshops, seminars, as it relates to agriculture and climate change issues and are more willing to take steps in overcoming the changing climate and its associated risks such as frequent floods, severe windstorms, late onset of rain, and early cessation of rain. These risks, if not tackled ahead of time affects agricultural production negatively [36].

The household size of the farmers had a significant positive relationship with late onset of rain and also was negatively related to frequent floods. This implies that household size is a significant determinant of the perception of farmers to climate events. That is the larger the household size of a farmer is, the more likely he/she would be in perceiving the late onset of rain. This is likely given the higher number of persons in the household and each active member of the family has the ability to observe and record any change in the onset of the rains. Family labour is mainly seen as an outcome of large household size which could be utilised in managing climate events perceived. The negative relationship with frequent flood implies that families with fewer members noticed flooding more than their counterparts with larger members.

Off-farm employment also had a positive significant relationship with early cessation of rain. This means that farmers involved in off-farm employment noticed early cessation of the rains than their counterparts not involved in any off-farm employment. Off-farm employment could take members of farm households to other locations with different climates from their homes and this might lead them to noticing changes in the timing of rains. Generally, off-farm employment offers the farmers the opportunity to seek any other jobs outside their primary occupation (farming), and as a result, the farmers are being exposed to climate change activities and its associated risks with possible means of counteracting its negative effects.

Gender had a negative and significant relationship with a prolonged dry season and rising temperature. This shows that climate change perception by rice farmers is not gender-neutral. The negative significant relationship with the prolonged dry season and increased temperature implies that female rice farmers noticed prolonged dry season and rising temperature more than their male counterparts. This could be probably due to the serious engagement of the female farmers [65] and women's vulnerability to increasing temperature and associated risks. Nowadays women tend to engage more in farming activities and are also being exposed to climate change risks and their possible impacts.

Ownership of television and mobile phone also had a negative significant relationship with late onset of rain. This implies that ownership of television had a negative influence on the perception of late onset of rain. Ownership of television and mobile phone grants farmers access to more diverse and well-analysed climate information that could be matched with their perception. In situations such as this, farmers will reconcile perception with scientific information [20]. Moreover, sometimes farmers that have television may not have the time to watch the television due to tight engagements [35].

Membership of farmers' groups/associations had a significant positive relationship with prolonged dry season, showing the influence of farmers' groups in shaping the perception of the farmers to climate events (in this case prolonged dry season). Members of farmer groups are better positioned to access information on climate events which ordinarily may elude them if they do not belong to such groups. Farmers' groups have a way of inculcating and disseminating vital information concerning new farming methods, agricultural innovations, climate change and its associated risks with improved ways to manage the risks [37].

Marital status also had a significant positive relationship with prolonged dry season and unpredictable rainfall pattern and distribution in the area. This posits the influence of marital status in local perception of climate change. In this case, the significant positive relationship with prolonged dry season and unpredictable rainfall pattern and distribution connotes that these climate events were perceived more by the married farmers than their colleagues who are single. This could be true because married farmers seem to be more disposed to information relating to agricultural activities compared to their single counterparts. Marriage enhances the capacity of the farmers in accessing reasonable and vital information [37].

3.4. Interdependent Nature of Perceived Climate Events

The joint perception of climate events is shown in Table 3. The Chi-square, which determines the appropriateness of the MVP model, is significant at 1% level. This indicates that the MVP is appropriate in modelling the determinants of perceived climate events in rice production. Table 3 indicated that the perceived climate change events are only complementary. This implies that all the perceived climate events in the area complemented each other and existed amongst the farmers. The result consists of 28 pairwise correlation coefficients of the perceived climate events. All the correlation coefficients of the perceived climate events were positive. Amongst the 28 correlation coefficients, 25 were positively significant, while the remaining three were not significant. The results showed that increased rainfall intensity was significant and complemented frequent floods, increased temperature, late onset of rain and early cessation of rain. Increased rainfall intensity causes soil displacements and erosion, which can harm rice fields and destroy planted rice grains. Furthermore, higher rainfall intensity might result in flooding, reducing rice yields and affecting the local food security situation [35]. Frequent floods are known to undermine plant structures, causing total collapse of the rice plants. The soil and water conditions present during flooding usher in the growth of microbial diseases organisms. Increased temperature encourages the growth of soil pathogens, which spawn insect attacks and pest/diseases in rice fields, reducing rice yields, outputs and income [38]. Rice reproductive and developmental stages are hampered by high temperature, which reduces plant height and root extension. Early cessation of rainfall promotes poor aeration of the soil and decreases moisture root content, resulting in poor rice crop growth and yields [66].

Prolonged dry season was significant and complemented frequent floods, severe windstorm, and unpredictable rainfall pattern and distribution, late onset of rain and early cessation of rain. This implies that these perceived climate events complemented each other. Long dry season reduces soil moisture content, denying planted grains access to the moisture they need for growth and crop development. Drought could be triggered by a protracted dry season, causing considerable harm to rice crops. Frequent flood complemented increased temperature, severe windstorm, unpredictable rainfall pattern and distribution, late onset of rain and early cessation of rain. Severe windstorms can have a significant impact on rice production, causing substantial damage and causing fractures, bends, and other sorts of injuries that result in yield and productivity loss. Increased temperature was significant and complemented severe windstorm, unpredictable rainfall pattern and distribution, late onset of rain, and early cessation of rain. Farmers find it extremely difficult to plan their farming operations due to the unpredictable rainfall

pattern and distribution. Rainfall is unpredictable, which disrupt the planting schedule and leaves farmers defenceless during planting seasons. Severe windstorm was significant and complemented unpredictable rainfall pattern, late onset of rain, and early cessation of rain. Late rains disrupt farmers' planting schedules, causing lengthy delays in rice farming, particularly highland rice cultivation, and resulting in low yields or product [35].

Table 3. Interdependency of the perceived climate events.

	Increased Rainfall Intensity	Prolonged Dry Season	Frequent Floods	Increased Temperature	Severe Windstorm	Unpredictable Rainfall Pattern and Distribution	Late Onset of Rain	Early Cessation of Rain
Increased rainfall intensity	1.000							
Prolonged dry season	0.107	1.000						
Frequent floods	0.229 **	0.525 ***	1.000					
Increased temperature	0.320 ***	0.183	0.400 ***	1.000				
Severe windstorm	0.391 ***	0.317 ***	0.478 ***	0.377 ***	1.000			
Unpredictable rainfall pattern and distribution	0.170	0.266 **	0.253 **	0.551 ***	0.645 ***	1.000		
Late onset of rain	0.404 ***	0.484 ***	0.394 ***	0.446 ***	0.650 ***	0.618 ***	1.000	
Early cessation of rain	0.290 ***	0.469 ***	0.430 ***	0.238 **	0.664 ***	0.406 ***	0.643 ***	1.000

*** $p < 0.01$; ** $p < 0.05$.

Unpredictable rainfall pattern and distribution was significant and complemented late onset of rain and early cessation of rain while late onset of rain further complemented early cessation of rain [36]. The interdependent nature of the perceived climate events indicated that farmers in the area have experienced one form of climate events or the other and had also adopted various climate change adaptation strategies in mitigating their negative effects on rice crops in the area.

Likelihood ratio test of $\rho_{21} = \rho_{31} = \rho_{41} = \rho_{51} = \rho_{61} = \rho_{71} = \rho_{81} = \rho_{32} = \rho_{42} = \rho_{52} = \rho_{62} = \rho_{72} = \rho_{82} = \rho_{43} = \rho_{53} = \rho_{63} = \rho_{73} = \rho_{83} = \rho_{54} = \rho_{64} = \rho_{74} = \rho_{84} = \rho_{65} = \rho_{75} = \rho_{85} = \rho_{76} = \rho_{86} = \rho_{87} = 0$: $\chi^2(28) = 290.11$ Prob > $\chi^2 = 0.000$.

3.5. Climate-Smart Agricultural Practices/Technologies in Rice Production

The authors first grouped and renamed some climate-smart agricultural strategies before having the final eleven strategies subjected to principal component analysis. Organic and inorganic fertilizer were grouped together and renamed effective use of fertilizer, while seeking early warning information about climate risks and using weather forecasting were grouped together and renamed reliance on climate information and forecasts. The climate-smart agricultural practices were reduced to eleven and principal component analysis was carried out to determine the broader categorization of the practices and the result presented in Table 4. The rotated component matrix of the climate-smart agricultural strategies adopted by the rice farmers is shown in Table 4. From the result, a threshold value of 0.500 was established and was used as the basis for determining the principal components. The first principal component (PC1) was highly correlated with three of the climate-smart agricultural strategies namely (planting improved rice varieties, soil and water conservation techniques, and adjusting planting and harvesting dates) and yielded scores of 0.783, 0.709 and 0.705 respectively. We named this component crop and land management practices. This component supports all around bio-physical development of the crop and soil leading to improved yields and outputs [10,18,67]. It is still evidently clear that planting improved rice varieties is a key climate-smart agricultural strategy. Improved

rice varieties are high yielding varieties and are highly resistant to rice pests and disease infestations. Furthermore, improved rice varieties especially early maturing varieties reduce methane emissions from rice farms by reducing the length of the growing season, which is a measure of the length of time paddy rice fields are flooded and emit methane. Additionally, soil and water conservation is another critical climate-smart agricultural strategy which ensures minimal destruction of the soil surface and renewal of adequate moisture contents of the soil required for maximum growth and crop yields [21,35,39] and reduces emissions of greenhouse gas. Water and soil conservation helps in managing the emissions from paddy rice fields especially through intermittent aeration of the field. More so, adjusting planting and harvesting dates is seen as an effective crop and land management practice that enables rice farmers to adjust their planting and harvesting calendars to suit any prevailing climate change which, if not adhered to might cause havoc on planted rice crops [10].

Table 4. Rotated component matrix result of rice farmers' climate-smart agricultural strategies.

Climate-Smart Agricultural Strategy	Component				
Individual Climate-Smart Agricultural Strategies	Crop and Land Management Practices (PC1)	Climate-Based Services and Irrigation (PC2)	Livelihood Diversification and Soil Fertility Management (PC3)	Efficient and Effective Use of Pesticide (PC4)	Planting on the Nursery (PC5)
Planting improved rice varieties	0.783 **	−0.091	−0.181	0.178	−0.102
Insurance	0.009	0.711 **	0.210	0.249	−0.070
Planting different crops	0.418	−0.216	0.502 **	0.337	−0.157
Livelihood diversification	−0.012	0.146	0.839 **	−0.063	−0.109
Soil and water conservation techniques	0.709 **	0.241	0.166	−0.270	0.048
Adjusting planting and harvesting dates	0.705 **	0.195	0.068	0.081	0.191
Irrigation	0.028	0.731 **	−0.167	−0.332	−0.093
Reliance on climate information and forecasts	0.282	0.574 **	−0.079	0.099	0.203
Planting on the nursery	0.072	0.011	0.046	0.030	0.929 **
Proper application of fertilizer	−0.031	−0.122	0.679 **	−0.019	0.338
Efficient and effective use of pesticide	0.049	0.084	−0.038	0.875 **	0.041

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. a = Rotation converged in 6 iterations. ** signifies components with score of 0.5 and above and selected components. PC 1 was renamed crop and land management practices. PC 2 was renamed climate-based services and irrigation. PC 3 was renamed livelihood diversification and soil fertility management. PC 4 was efficient and effective use of pesticide. PC 5 was planting on the nursery.

The second principal component (PC2), which is climate-based services and irrigation, is highly correlated with another three climate-smart agricultural strategies (irrigation, insurance, reliance on climate information and forecasts). Amongst the climate-smart agricultural practices/technologies, irrigation had the highest score of 0.731. Irrigation ensures efficient and sustainable supply of water to the planted crops all through the farming season [68,69]. Efficient water management and intermittent draining of paddy rice fields are very important strategies for reducing and avoiding methane emissions. Insurance with a score of 0.711 indicated that insurance is a vital adaptation strategy which covers the farmer during periods of total agricultural failure occasioned by climate change [45]. Reliance on climate information and forecasts is another important climate-

smart agricultural strategy that assists farmers with current information on climate change. The climate information services empower the farmers to respond favourably to the adverse effects of climate change in the area.

Similarly, the third principal component (PC3) again, categorized another three climate-smart agricultural strategies (livelihood diversification, appropriate application of fertilizer, and planting different crops), which had principal component scores of 0.839, 0.679 and 0.502, respectively, into one component. This component is called livelihood diversification and soil fertility management. These are climate-smart agricultural techniques employed to improve the living standard and/or condition of the rice farmers as well as improvement of the soil fertility, crop yields and productivity of the rice farmers in the area [21] and reduction of greenhouse gases in the area. Livelihood diversification helps the farmers especially the poor ones in raising additional sources of income outside their primary occupation and this income assist heavily in family support [70,71]. Appropriate application of fertilizer and planting different crops are beneficial climate-smart agricultural strategies. Appropriate application of fertilizers improves the soil fertility leading to bumper growth and harvest, avoids wastage of fertilizer which may lead to increased nutrient losses to the environment and increase emissions. Planting different crops serves as an alternative cover for the farmer in times of crop losses due to climate change [72].

The fourth principal component (PC4) and the fifth principal component (PC5) were an efficient and effective use of pesticides and planting on the nursery respectively. These climate-smart agricultural strategies had scores of 0.875 and 0.929, respectively. In combating rice pests and diseases, efficient and effective use and applications of pesticides is quite necessary to drive efficient growth processes and plant developments without many struggles [73]. Adoption of this practice empowers farmers to tactically reduce the effects of rice pests on the farmlands, give room for maximum growth and higher yields and reduce emission of any chemical that may contribute to global warming. Planting in the nursery is a suitable adaptation strategy, where the tender crops are first planted before being taken to the permanent field. This ensures maximum protection of the planted crops from the vagaries of climate. This practice enables farmers to properly tend the growing rice plants before transferring to the field and helps in protecting the growing rice plants from the negative effects of climate change. In addition, the rotated matrix of the adaptation strategies showed that none of the adaptation strategies were less than the threshold value of 0.500.

3.6. Constraints to Adoption of Climate-Smart Agricultural Practices in Rice Production

Figure 3 presents the constraints to the adoption of climate-smart agricultural strategies in rice production in the area. Figure 3 showed that 98.6 per cent of the rice farmers indicated the high cost of fertilizer as their major barrier to uptake of climate-smart agriculture in the area. As a result of the devastating effects of climate change, soil fertility is majorly affected influencing the poor performance of the harvested crops, as such the only way out is the application of fertilizers [10]. The high costly nature of fertilizer tends to mar its effective and efficient applications thus, posing a huge challenge in responding to climate change. About 83 percent of the rice farmers averred lack of inputs access as their constraint to uptake of climate-smart agriculture. Access to farming inputs (improved varieties, seedlings, pesticides, etc.) facilitates farmers' response to climate change. However, the inability of the farmers to access inputs could become a barrier in responding to climate change [11,74,75]. Inadequate land was reported by about 76.1 percent of the rice farmers. Inadequate land restricts the full practices or application of some of the climate-smart agricultural strategies or techniques. In reality, adequate land is required to technically practice some of the climate-smart strategies especially soil and water conservation techniques, planting of different crops, etc. to fully maximize its benefits and rewards. When the land is fragmented or inadequate in some cases, it distorts the benefits of climate risk management [30] and this may kill the drive and interest of farmers in responding to climate change. Inadequate capital was observed by about 93.4 percent of

the rice farmers as a serious constraint to uptake of climate-smart agriculture. Inadequate capital makes it difficult for farmers to access some of the farming inputs such as lands, labour, planting materials, etc. Whereby these farming inputs are not readily accessed, responding to climate change becomes extremely difficult [75]. Moreover, capital is seen as a key determinant to climate change resilience, mitigation, rice productivity and food security. Pests and diseases were also reported by 86.2 percent of the rice farmers as a major barrier to adoption of climate-smart rice production technologies/practices. Pests and diseases are usually triggered by prolonged drought and high-temperature conditions occasioned by climate change and as such attack rice crops reducing the quantity, quality and productivity of the farmers, thus posing a trait to climate change adaptation and mitigation [76]. About 58.2 percent of the rice farmers indicated flooding as a limitation to uptake of climate-smart agriculture. Flooding alters the level of plant-available nutrients in the soil by way of washing off both the sub and topsoil surfaces thereby weakening the defence mechanism of plant roots. In addition, flooding causes water percolation which breeds all manner of plant diseases and pests that attack planted crops, and hinder rice farmers resilience and mitigation to climate change [77]. Scorching sun was also pointed out by about 63 percent of the rice farmers. The high intensity of the sun sometimes makes it difficult for the farmers to respond to climate change. About 87 percent of the rice farmers attested to high labour cost as a major constraint to adopting climate-smart agriculture in rice production. Labour is evidently required to efficiently practice and apply climate-smart rice production strategies/techniques by the farmers. Where the labour is costly more especially hired labourers, it becomes extremely difficult to respond to climate change. Sometimes the exorbitant fare charged by hired labourers makes it challenging for some of the poor and vulnerable farmers from accessing them thus complicating their chances to respond to climate change [74]. Inadequate climate information was reported by 68.3 percent of the rice farmers. Inadequate climate information services limit the farmers' knowledge in responding to climate change. Where the farmers are not properly informed about the activities of climate change, they are bound to be overwhelmed and susceptible to climate change issues thereby limiting their response [11]. Consequently, poor extension services were reported by about 54 percent of the rice farmers. Extension service is another enabler of uptake of climate-smart agriculture in rice production. It is a mirror to the adaptation and mitigation strategies and empowers the farmers on some of the technicalities associated with some of the climate-smart strategies and their corresponding benefits and advantages over others. Extension services help farmers to access first-hand information on climate change on time and how to overcome and adapt to them favourably but where these services are not readily available or poorly delivered, the tendencies of the farmers to effectively respond to climate change become limited [74]. However, appropriate seminars, conferences, symposiums; etc. that will spur the farmers' productivity, climate change mitigation and resilience should be encouraged. Additionally, policy drive should be tailored toward overcoming the above-identified constraints in the uptake of climate-smart agriculture in rice production.

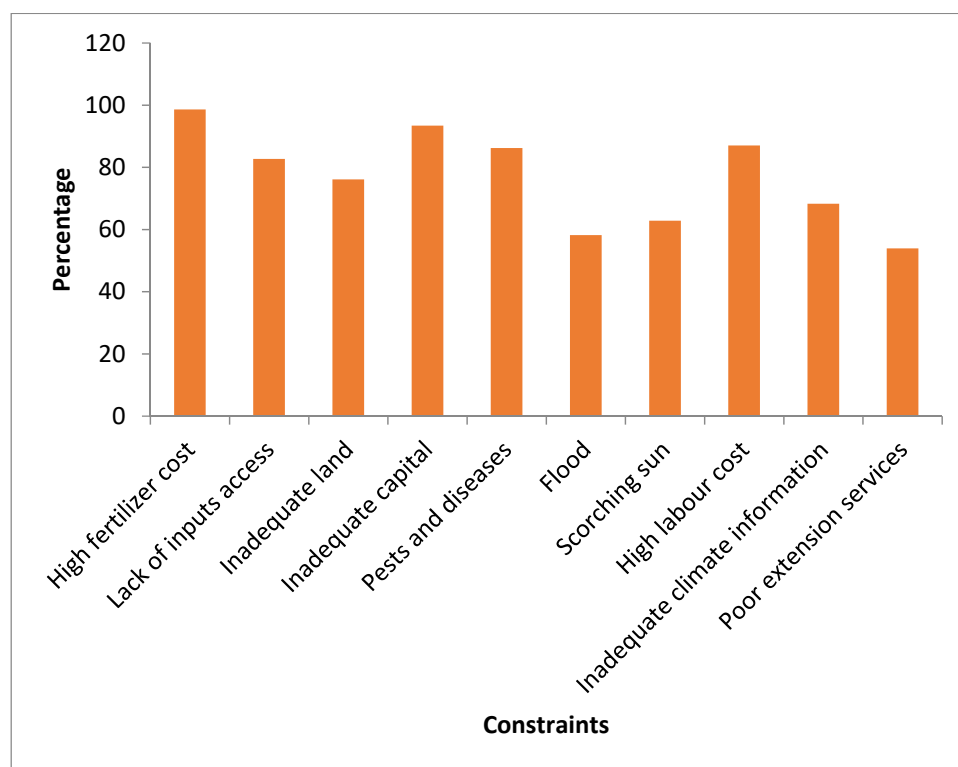


Figure 3. Constraints to adoption of climate-smart agricultural practices/technologies in rice production.

4. Conclusions and Recommendations

Climate change poses a serious challenge to rice production in many parts of Africa and rice farming also contributes significantly to greenhouse gas emissions. Farmers perceive different effects of climate change on rice production and have also responded differently. Climate-smart agriculture is needed as an important strategy to respond to climate change in Sub-Saharan Africa. However, the adoption of climate-smart agriculture in rice farming is still low in sub-Saharan Africa. To increase the understanding of rice farmers' perception on climate change and uptake of climate-smart agriculture in rice production, this study was conducted using cross-sectional data from three hundred and forty-seven rice farmers and analysed using principal components, multivariate probit regression model and descriptive statistics.

Farmers perceived various climate events such as increased rainfall intensity, prolonged dry season, frequent floods, increased temperature, severe windstorm, unpredictable rainfall pattern and distribution, late onset rain and early cessation of rain. Several socioeconomic characteristics and assets of the farmers determined the perception of climate change in rice production. Education, age, household size, gender, off-farm employment, ownership of television and mobile phone, membership of farmers groups and marital status were the main drivers of climate change perception in rice production. Additionally, perceived climate events are largely interdependent and complementary to each other.

In a bid to overcome perceived climate events, the rice farmers adopted several climate-smart agricultural strategies. These include planting improved rice varieties, insurance, planting different crops, livelihood diversification, soil and water conservation techniques, adjusting planting and harvesting dates, irrigation, reliance on climate information and forecasts, planting on the nursery, appropriate application of fertilizer and efficient and effective use of pesticides. The principal component analysis showed that the individual climate-smart agricultural practices can actually be disseminated as bundles of strategies in packages. This study has shown that farmers' perception on climate change plays

significant role in the decision to respond to climate change in rice production. Therefore, incorporating farmers' perception on climate change and indigenous knowledge into adaptation and mitigation planning will be an effective and efficient way of increasing rice productivity and resilience to climate change. The major barriers to uptake of climate-smart agriculture by rice farmers include high fertilizer cost, lack of inputs access, inadequate land, inadequate capital, pests and diseases, flood, scorching sun, high labour cost, inadequate climate information and poor extension services. Thus, the farmers are advised to constantly seek information on climate change before embarking on rice production, this will without doubt position them to overcome any adverse effect of climate changes. Additionally, the government should assist the farmers in implementing climate change policies to ameliorate the sufferings and constraints of the rice farmers.

This study focused more on smallholder rice farmers in Ebonyi State, Nigeria. Future studies could extend the scope to Nigeria to allow for comparisons across different rice-producing agro-ecologies regarding perception, uptake of climate-smart rice production technologies and barriers to the adoption of such technologies. Such studies could also extend the analysis to ascertain the effect/contribution of adoption of different climate-smart rice production practices on rice yield, food security, resilience and mitigation. This is particularly important given the importance of rice production to Nigeria's economy and the vulnerability of rice cultivation to climate change.

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