Volume XVII Number 2, 2025

Analysis of Determinants of Maize Farmers Adaptation Strategies to Climate Change in South-South Nigeria

Adeyinka Richard Aroyehun[1], Anthony Ojonimi Onoja[1,2], Vivian Chinelo Ugwuja[1]

[1] Agricultural Economics and Agribusiness Management Department, University of Port Harcourt, Nigeria

[2] Department of Agriculture and Animal Health, College of Agriculture and Environmental Sciences, University of South Africa (UNISA), Johannesburg, Republic of South Africa

Abstract

Adaptation to climate change is critical for sustainable livelihood in developing countries like Nigeria where agriculture production depends majorly on rainfall. This research examined the analysis of determinants of maize farmers' adaptation strategies to climate change in South-South Nigeria. Multistage sampling techniques were used for the selection of 260 maize farmers from 36 communities in the study area. Primary data were collected using a set of questionnaires and an interview schedule. The result of the Variance Inflating Factor (VIF) and Tolerance level revealed that multicollinearity does not exist. The majority (96.9%) of the maize farmers adopted the use of adaptation techniques. The majority (81.9%), (81.5%), and (78.5%) adopted the use of improved crop species, planting of drought tolerant crop species, and changing in planting dates respectively. The multivariate probit (MVP) model results show that among all determinants, access to information on climate change was the most important influencing factor that enabled farmers to adopt different adaptation strategies because it was statistically significant in all the dependent variables used in the analyses. The research, recommends collaboration among the tiers of institutions to improve access to credit/ finance facilities, avail affordable farm inputs, adequate extension service delivery, eliminate the risk of maize pests and disease, and provide necessary and timely information for the maize farmers.

Keywords

Adaptation, climate change, diversification, mixed farming, MVP.

Aroyehun, A. R., Onoja, A. O. and Ugwuja, V. C. (2025) "Analysis of Determinants of Maize Farmers Adaptation Strategies to Climate Change in South-South Nigeria", *AGRIS on-line Papers in Economics and Informatics*, Vol. 17, No. 2, pp. 3-23. ISSN 1804-1930. DOI 10.7160/aol.2025.170201.

Introduction

The global average temperatures have significantly increased since the Industrial Revolution (Baumann, 2018). The Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change IPCC (2021) provides strong evidence for the increasing trend of global mean temperature in the 21st century. The rising trend in temperatures due to greenhouse gas emissions has contributed to global warming. Global warming increased by + 1.07°C (0.8–1.3°C; likely range) for 2010–2019 compared to the reference period 1850–1900 (IPCC, 2021). Gemeda, Korecha, and Garedew (2023) noted that there are more hot days and fewer cold temperature extremes projected in most places as global mean temperatures increase. Increase in population growth and stressors on agricultural productivity triggered by climate change, have a significant impact on food security (Dasgupta and Robinson, 2022; Kumar et al., 2022; Rahut et al., 2022). Hence, it could be widely recognized that climate change is having an adverse effect on food security.

Climate change has induced an adverse impact on all sectors of the economy with high severity on rain-fed agriculture due to its sensitivity. Climate change affects agricultural yields and thus may increase food insecurity in the absence of adaptation options (IPCC, 2019; Mequannt et al., 2020). Hence, irreversible climate change threatens food supplies, including Nigeria, especially South-South Nigeria. The decline in agricultural production is one of the key factors to poverty as climate change significantly affects food supplies (Abbass et al., 2022). To enhance public awareness of the interlinkages between climate change and food security, the 27th UN Climate Change Conference of the Parties in 2022 made food systems part of the agenda of COP27. It has been reported that climate change can reverse food security improvements in Africa (Dasgupta and Robinson, 2022). Various adaptation strategies and policies have been made so far to minimize the effects of climate change on agriculture. Like other countries, Nigeria is experiencing climate change.

Previous studies conducted on climate change adaptation include Kabira, Alauddinb, and Crimp (2017); Mercer (2020); Ogunnaike, Oyawole, Afolabi, and Olabode (2021); and Aroyehun (2023) among others, noted that climate change influences the seasonal variability's that severely affecting agricultural output and the livelihood of the farmer's. Changes in rainfall and temperature from normal conditions can significantly affect agricultural production. Hence, climate change is impacting Nigeria's agricultural production and economy. Agricultural yield reductions and food insecurity caused by climate change continue to be the major concerns affecting the nutritional needs and food preferences of agricultural communities. Increasing temperatures, changing precipitation patterns, and the occurrence of extreme events negatively affected food security (IPCC, 2019). As such, climate change adaptation strategies are designed to enhance agricultural productivity and build farmers' resilience (Bedeke et al., 2019). There is a great consensus that policymakers require climate information to advise the best adaptation strategies (Gebrechorkos et al., 2020). Therefore, maize farmers' understanding of climate change impact is the prerequisite information to design adaptation strategies. Yet, none of these studies examined the effects on maize farmers' adaptation to climate change: particularly, concerning Nigeria's maize production for society utilization. Some research like Adeagbo, Ojo, and Adetoro (2021); Aderinoye-Abdulwahab, and Abdulbaki (2021); Osuafor, Ude, and Ositanwosu (2021) has been done on maize and climate change adaptation but nor of this use multivariate probit (MVP) which this study want to fill, particularly to the effect of climate change adaptation strategies on maize farming in South-South Nigeria. Consequently, this current research attempts to close the aforementioned gap by exploring climate change adaptation strategies and maize production. This will provide evidence for policy on the efficient use of adaptation strategies in building maize farmers' productivity and resilience in a changing climate in Nigeria, especially in the South-South region of Nigeria. Given this, this research aimed to fill this knowledge gap by examining the effect of selected independent variables on climate change adaptation strategies adopted by the maize farmers; and analyze the determinants of adaptation strategies adopted by the maize farmers to cope with climate change impacts in South-South Nigeria in order to increase the speed of Nigerian's to achieve the Sustainable Development Goals (SDGs) of no poverty, zero hunger and climate action.

Literature review

Climate a phenomenon as well as a demonstration regarding weather and diverse atmosphere (baroscopic) conditions, has widely been recognized and accepted as one of the definite basic constituent indexes that determine crop farming and animal rearing. Climate is a long-term numerical mean of weather and other baroscopic conditions that directly and indirectly influence the function and performance of the farms (Aderinoye-Abdulwahab and Abdulbaki, 2021). Prevailing climatic conditions of any environment (biosphere) determine the selection of crops, mode of planting, and yields. According to Aderinoye-Abdulwahab and Abdulbaki (2021) biophysical component determinants for instance energy from the sunlight, temperature, moisture, wind, and humidity, including other climatic factors control and influence universal crop distribution, productivity and profitability. Conversely, climate change is the long-term variation in arithmetic medium point of temperature owing to the effect of the earth's warming that could ultimately transpose toward exhaustion or reduction of the ozonosphere stratification. Higher greenhouse gas (GHG) emission concentration into the troposphere results in earth warming (Mboera, Mayala, Kweka, and Mazigo, 2012). Human activities that advance contribution to GHG include the use of fossil fuel, changes in land utilization, and agricultural operations among others.

United Nations Framework Convention on Climate Change [UNFCCC] expresses climate change using any variation/ alteration in climatic factors covering an excessive length of duration (35 years), which could be either natural variation or due to human activity. In another way, the Intergovernmental Panel on Climate Change IPCC (2001 as cited in Onoja, Achike, and Enete, 2018), described climate alteration to be the deviation in a climate that is associated with direct and/ or indirect activity of human beings known to mutates constituent of the universal troposphere as well as substratosphere coupled with inherent fluctuations noticed over a comparable period. The World Bank (2016) reported the Paris Climate Conference informed that climate change, if abandoned or not attended to may be a "foundational hazard to the development of economy in our generation and capable of pushing over hundred (100) million people in abject poverty by 2030." This possibly will weaken all advancement achieved globally in combating poverty for about 18 years. Climate change is a great risk and uncertainty to the agricultural sector and socioeconomic development of the nation, agricultural production enterprises are more predominantly open to vulnerability attacks of climate change than any other sectors of the economy (Onoja et al, 2018). Hence, climate change poses a greater and increasing risk to food security globally.

Adaptation strategies to climate change are critical at the farm level, features such as increasing crop failures due to erratic rainfall, prolonged drought during growing, early termination of rainfall, crop loss as a result of storms and floods, increasing temperatures, and pest and diseases scourge compels for efficient adaptation. Adaptation to climate change involves taking appropriate and suitable actions to minimize the adverse effects of climate change by adopting relevant adaptation strategies. Climate change adaptation has three (3) potential objectives: to minimize exposure to the uncertainty of the hazard; to improve the ability and scope to tackle and manage the inevitable damages; and to annex the advantages of advanced new opportunities (Akinnagbe and Irohibe, 2014). Crop adaptation strategies to climate change impacts according to Akinnagbe and Irohibe (2014) are as follows: planting of drought-resistant species of crops; crop diversification; change in cropping and planting date pattern; mixed cropping; enhancement and optimization of irrigation infrastructure effectiveness; soil moisture conservation; afforestation (planting of trees) and agroforestry; labour migration; diversification of income; effective use of insurance; meteorological information; and farm-level financial management scheme. Table 1 below shows other (extracted) adaptation strategies adopted by crop farmers in sub-Saharan Africa as itemized by the World Bank (2008 as cited in Onoja, 2014).

Practice	Adaptation strategies
Crop and livestock improvement	
Crop rotations	Minimize weed completion with crops, and pest attacks; reduce depletion of particular soil nutrients.
Agroforestry practice combined with crops/ livestock	Increase soil nutrients via leaves, enhance water permeations, and reduce soil dryness.
Utilization of additional resources productive of crops, trees, and livestock	Enhances water and/ or nutrient utilization productivity both presently and in future climate change.
Enclosures	Facilitates metamorphosis of vegetation cover, valuable plants, and spring reclamation.
Enhanced grazing methods	Preservation and reformation of vegetation cover and minimize soil compression.
Safekeeping of vegetation from fire incidence	Conservation and protection of vegetation and essential varieties
Soil management improvement	
Cover cropping	Minimize soil erosion, and weed growth and support soil carbon accumulation.
Mulching and compost	Minimizes soil erosion, and increases soil moisture maintenance, soil nutrients, and organic matter.
Manure application	Improves soil organic matter
Crop residue inclusion	Addition of nutrients and organic matter to the soil
Intercropping with legumes	Enhances infiltrations, soil nutrients, and carbon improvement via nitrogen fixation
Terrace planting	Prevents soil erosion
Minimal tillage	Improves soil moisture and accelerates soil carbon
Windbreaks and protection supports	Minimizes winds and rain erosions
Water management improvement	
Contour farming/ planting	Equally proportioned water circulation and penetration in sloppy areas, and minimizes water runoff and overflow.
Harvesting of rainwater	Rainwater storage in tanks or ponds compensates for prolonged drought periods
Establishment of irrigation systems	Compensates impacts of drought periods. Restrain farmland accumulation of excess water.
Management of watershed	Adequate and efficient management of rainwater, surface, and underground waters should be adopted at the hierarchy beyond the household level.

Source: Authors

Table 1: Crop farmers' adaptation strategies.

Maize production

Maize is widely well-known to be the Queen of cereal crops because of its requirement and vast adaptability. It is the second most essential cereal crop globally to land expanse and yield. Maize production globally was about 1040 million metric tons (MT) in the years 2016-2017, where USA and China output contributions were 38% and 23% respectively (Jaidka, Bathla, and Kaur, 2019). Maize is the third major vital food crop subsequently to rice and wheat crops in India. Whereas, maize is the main cereal crop and one of the major vital and essential food crops in Nigeria (Kamara, Kamai, Omoigui, Togola, Ekeleme and Onyibe, 2020). Maize's genetic resilience has made it the largest broadly planted crop in Nigeria from the Coastal evergreen climate region of the forest zone to the dry Sudan savannah region. Maize is photoperiod indifferent; these make it grow at any time of the year, giving it better adaptability to fit into various cropping systems.

In Nigeria, maize has become a vital crop, taking over expansive land from common crops like millet and sorghum. Maize yield in Nigeria in the year 2018 was about 10.2 million tons from 4.8 million hectares of land (Fig 1), making Nigeria the largest maize producer in Africa (FAO, 2018 as cited by Kamara et al, 2020).

Scientific work and results by crop breeders and agronomists have resulted in the adaptability of maize to innovations such as drought-resistant species, high-producing species, and diseases-resistant, low nitrogen among others. However, despite various availabilities of maize species, outputs are yet low in Nigeria to meet up with the population increase.

Maize can be grown favourably and profitably on loamy sandy to massive clayey soils, well-aerated soil, and soils with neutral pH. Maize originated from Central America and Mexico, which in Mexico existed significantly for about 5000 years ago with different maize crop species. Maize is of tropical origin, is very susceptible to water stagnation, and poorly drained farmland (Jaidka et al, 2019). In addition, extensive low temperature of about less than 5oC exclusively affects the yields of maize. The optimum temperature range for maize optimal growth and yield is 21-35°C (Jaidka et al, 2019), with rainfall distribution of 480-880 mm for proper yield (Kamara et al, 2020). Maize is day day-neutral crop, it can be grown all year around which results in high output levels in a very short time. Maize cultivar selection depends on temperature and volumes of moisture content in the soil. Table 2 below shows maize cultivars according to Jaidka et al. (2019).

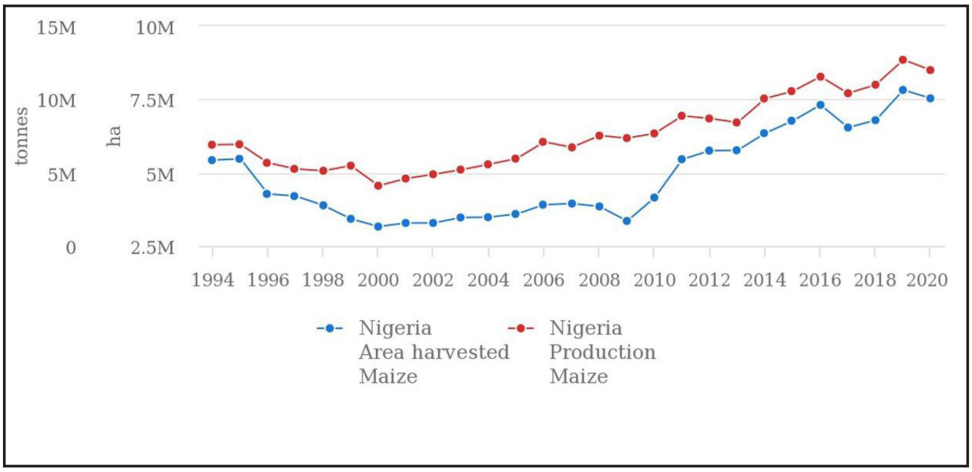
Kind of maize cultivar	Length of maize cropping period (in days)
Early maturity	80-90
Medium maturity	90-100
Late maturity	100 and above

Source: Authors

Table 2: Maize cultivars.

The effect of climate change on the agricultural system in the study area

South-South Nigeria, which includes the States of Rivers, Bayelsa, Delta, Cross River, Akwa Ibom, and Edo, is particularly sensitive to climate change due to its coastal position and reliance on agriculture. Frequent floods, increasing sea levels, coastal erosion, and shifting rainfall patterns



Source: Authors computation (2023)

Figure 1: Maize production trends in Nigeria (yields).

all have a significant impact on agricultural output and livelihoods (Nigerian Meteorological Agency NIMET, 2015). The primary consequences of climate change on agriculture in the region include:

Flooding and coastal erosion: Intense rains and inadequate drainage systems have resulted in regular floods, notably in the Niger Delta. As a result, farmlands get submerged, crops are lost, and soil nutrients are depleted (NDDC, 2019). Coastal erosion also lowers maize land, jeopardizing food security in coastal populations (Akpodiogagaa and Odjugo, 2010).

Irregular rainfall patterns: Unpredictable rainfall disrupts planting and harvesting schedules, resulting in crop failures and decreased yields. Traditional agricultural calendars are becoming less accurate, pushing farmers to try novel planting tactics that may not always work (Adejuwon, 2005).

Increased temperature and heat stress: Rising temperatures cause heat stress in crops and cattle. Crops such as cassava, maize, and rice exhibit reduced production under excessive heat, while animals suffer from decreased fertility and increased disease prevalence (Ozor and Nnaji, 2011).

Salinity intrusion and soil degradation: Sea-level rise causes saline intrusion into freshwater systems and farmlands, lowering soil fertility and damaging crops like yam, cassava, and vegetables that are susceptible to salinity (Eze and Efiong, 2017).

Pest and disease outbreaks: Pests and illnesses thrive in warm, humid areas. For example, the prevalence of the Fall Armyworm, which destroys maize harvests, has been connected to changing climatic circumstances (Ifeanyi-Obi, Etuk, and Jike-Wai, 2012).

The socioeconomic effects of climate change on farmers in the region include:

- Reduced income and livelihoods: Climate-induced crop failures have a direct impact on household income, contributing to greater poverty in agricultural areas (IFAD, 2020).
- Food insecurity: Declining agricultural production jeopardizes food security in both rural and urban regions (FAO 2016).
- Migration and displacement: Farmland loss due to floods and erosion drives rural-urban migration, increasing demand for urban resources (UNDP, 2020).

Agricultural climate adaptation policies/ programmes relevant to the study area

Agricultural climate adaptation strategies and initiatives are critical in South-South Nigeria because the region is vulnerable to climate change impacts such as floods, coastline erosion, saline intrusion, and erratic rainfall patterns. The region's economy is strongly reliant on agriculture, making it critical to develop methods that improve resilience and sustainability. Agricultural climate adaption strategies and programmes relevant to the research region include:

National Adaptation Strategy and Plan of Action on Climate Change for Nigeria (NASPA-CCN): NASPA-CCN offers an extensive framework for tackling climate change implications in several industries, including agriculture. The strategy encourages sustainable land management, climate-resilient crop varieties, and integrated water resource management, all of which are critical in flood-prone areas like the Niger Delta (Federal Ministry of Environment, 2011).

Climate-Smart Agriculture (CSA) initiatives: The Federal Ministry of Agriculture and Rural Development (FMARD) is implementing CSA projects with help from international organizations like as the FAO and the World Bank to promote sustainable practices such as drought-tolerant crops, effective irrigation, and agroforestry. These methods serve to reduce the dangers of unpredictable rainfall and floods in South-South Nigeria (FAO, 2013).

National Agricultural Resilience Framework (NARF): NARF strives to improve agricultural resilience by using climate-smart technology, systems for risk management, and early warning techniques. Its emphasis on developing adaptive capability is crucial for the South-South, where farmers experience recurring flooding and soil degradation (FMARD, 2014).

FADAMA III programme (additional financing): While FADAMA III was initially designed to promote dryland agriculture, it also includes components that aid in climate adaptation in wetter places. It encourages effective management of water resources, flood control measures, and livelihood diversification to strengthen the adaptability of small-holder farmers in South-South Nigeria (World Bank, 2020).

The Green Alternative (Nigeria's Agricultural Promotion Policy APP (2016-2020)): The APP, also referred to as the Green Alternative, emphasizes agricultural production, sustainability, and resilience. It fosters the use of climate-smart agricultural practices, better extension services, and the creation of flood-resistant crop varieties, which are especially pertinent to the climate conditions in South-South Nigeria (FMARD, 2016).

Niger Delta Development Commission (NDDC) climate adaptation initiatives: To address climate-related concerns such as coastal erosion and saline intrusion, the NDDC has implemented region-specific initiatives like as the restoration of mangrove forests, flood control systems, and environmentally friendly aquaculture programs (Ogbodo, 2022).

International climate adaptation programmes: International organizations, such as the International Fund for Agricultural Development (IFAD) and the United Nations Development Programme (UNDP), fund programmes that aim to improve smallholder farmers' climate resilience through capacity building, access to climate information, and sustainable agricultural practices (IFAD 2020; UNDP 2020).

Theoretical framework

The theory appropriate to this research is the theory of utility which is related to individual or corporate decisions. Utility simply means the satisfaction (adaptation) that each selection gives (benefit) to the actual decision-maker (farmer). Theoretically, utility comprises all the factors that affect the adaptation strategies' decision perspective of the maize crop farmers' psychology, culture and production. Hence, aforementioned utility theory appropriates that any decision (adaptation strategies adopted) follows the principle of utility maximization based on the best option chosen that gives the ultimate utility (that is satisfaction) to the farmer who makes the decision (Otitoju, 2013). In utility theory, $U(x)$ is a consumer's (like maize crop farmers) utility for definite sort of items X (like adaptation strategies), if the farmer assumes, that the utility derived from Y is not higher than the utility derived from Z, in this case, the expression will be $U(y) \leq U(z)$, or $y \leq z$. For the adaptation strategies question, if 'the adaptation strategy of u is not larger than the adaptation strategy v' then, we can express this type of ineffective selection using this symbol mark '$\precsim$' to evaluate orders and write it thus as $u \precsim v$ (Jian and Rehman, 2016). In all cases actual utility (satisfaction) well known to the decision-maker (maize crop farmer) derives by choosing a distinct climate change adaptation strategy is gauged and calculated through a utility function U, which is a measurable portray of actual decision-makers (that is maize crop farmer) strategy of alternative and preferences such that; $U(X_1)>U(X_2)$, where the preferred climate change adaptation strategy X_1 is adopted instead of X_2 or $Ux_1= Ux_2$, where adoption of X_1 is indifferent from the adoption of X_2, that's both adaptation strategies are preferred equally or give equal utility. Hence, the total utility from many available quantities of strategies for adaptation depends on the socio-economic typical feature of the individual maize crop farmers, and then total utility is; $U = f(X_1, X_2, X_3 \dots X_n)$. Utility can be stated thus;

$$U_t = U_1(X_1) + U_2(X_2) + U_3(X_3) + \dots + Un(Xn)$$

Therefore, the total utility of the climate change adaptation strategies of the maize crop farmers depends and the function of the available strategy. The climate change adaptation strategies were modeled into the production of the actual maize crop farmers' production activities in South-South Nigeria. Descriptive statistics were utilized to identify the climate change adaptation strategies utilized and adopted by the maize crop farmers in South-South Nigeria.

Another theory relevant is the theory of change. The theory of change is an approach that describes how a certain intervention or group of interventions, is anticipated to induce and give rise to definite development change, outlined on a causative analysis centered on obtainable substantiate evidence and sign (United Nations Development Group UNDG, 2017). Hence, a theory of change for the maize crop farmers should be driven by firm and reliable analyses, discussion with the major stakeholders, and ascertaining what strategies climate change adaptation adopted that are efficient and do not in different contexts described in the study. Theory of change aids in ascertaining solutions to efficiently tackle the causes of the problems that hamper strategies and adaptation as well as guide farmers' decisions on which climate change adaptation should be adopted, considering equivalent benefits, efficiency, and risks as well as uncertainties that are associated with any change processes (UNDG, 2017; Pringle and Thomas, 2019). Theory of change likewise aids in recognizing the fundamental assumptions and associated risks that are crucial to comprehend and reevaluate all through the adoption to guarantee the adaptation strategies that will enhance the anticipated change of the maize farmers which is high productivity and profit. Theory of change can be linked with adaptation strategies and improve relationships throughout climate change adaptation areas and measurements (Pringle and Thomas, 2019). The theory of change outlines the linkage between a long-term goal of adaptation adopted and the initial to average changes needed to bring the desired productivity (Bours, McGinn, and Pringle, 2014; Pringle and Thomas, 2019).

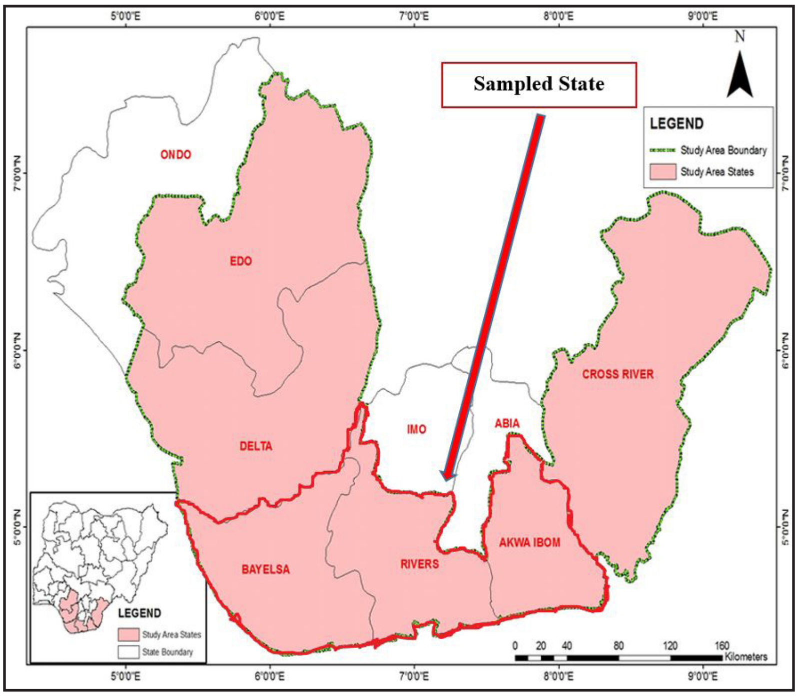
Additionally, the action theory of adaptation to climate change is appropriate for this study. The action entails actors and purpose, this purpose focuses directly on the repercussions of climate change, which involves the utilization of resources as a way to accomplish the desired ends of productivity (Eisenack and Stecker, 2011). The difference between prospective adaptation and definite adaptation adopted required showing momentary magnitude of climate change. Adaptation is governing decision-making procedures and actions that ensure improvement in the adaptive capacity of the farmers (Bours, McGinn and Pringle, 2014). Adaptation is also the rate of control variables that avert climate becoming susceptible. Essentially, the action theory of adaptation to climate change acknowledges farmers are prone and possibly face unanticipated challenges and require redirecting adaptation plans (Pringle and Thomas, 2019). This is coherent with adaptation planning which involves a continuous process of readjustment. The theory of change has been formulated and incorporated into climate change adaptation. Hence, the theory of change and the action theory of adaptation to climate change are inseparable. Climate change adaptation theory is actual actions that minimize the hazard consequence of climate change on maize crop production while taking benefit of the prospective new opportunities.

Materials and methods

Study area

The research was carried out in the South-South zone of Nigeria. The natural boundaries of the South-South zone can be distinct by its topography and hydrographic nature. South-South region's northern boundaries are close to the divergence of the Niger River at Aboh, and the western and eastern boundaries are near the Benin River and the Imo River, respectively. The South-South region consists of Cross River, Edo, Rivers, Delta, Akwa-Ibom, and Bayelsa States. The Region has a population of about 29,812,989 projected for 2022 (National Population Commission of Nigeria NPC, 2020). South-South region land area covers about 84,587 km^2 of Nigeria's aggregate land area and the vegetation is characteristically tropical savanna, rainforest, mangrove, and monsoon (Ibrahim, 2020). Figure 2 shows the map of the study area.

The region consists of four distinctive ecological zones defined by both landscape and hydrological characteristics; they are coastal sandy barricade



Source: : Ukhurebor and Uzuazor (2020)

Figure 2: Map of the study area.

crest, mangrove swamp, freshwater swamp, and lowland rainforest zones (Arokoyu and Weje, 2015). The climate in the South-South zone favours the planting of cash crops like coconut, cocoa, cashew, oil palm, kolaunt, gum Arabic, sesame, and rubber among others. Arable crops cultivated in the zone include rice, cassava, maize, melon, yams, cocoyam, and sweet potatoes. Hence, this study focuses on maize as being a staple and most vulnerable crop to climate change effects.

Sampling procedure

Multistage sampling procedures were used in the selection of the maize farmers for the study. First, three (3) States were selected using a simple random technique from the six States. Secondly, all the agricultural zones were selected in each State, making twelve (12) agricultural zones selected. Thirdly, one (1) Local Government Area (LGA) was selected from each agricultural zone using simple random technique, making a total of twelve (12) LGAs in all. Fourthly, three (3) communities were selected from each LGAs using simple random technique making a total of nine (9) and eighteen (18) communities respectively from each State and thirty-six (36) communities in all. Lastly, from each community, ten (10) and five (5) maize farmers were selected respectively (based on the number of Agricultural Zones in the State) using a simple random technique. This makes a total sample size of two hundred and seventy (270) maize farmers selected for the study. A multivariate probit (MVP) model was used to analyze the data obtained using SPSS 25.0 and the multicollinearity of the variables was also tested.

A sample size estimator by Andrew Fisher and used by Kibuacha (2021) was adopted, with a confidence level of 90% (1.65) standard deviation of 0.5, and a margin error of 5%. The sample size estimator is stated as;

$$n = \frac{Z^2 * P(1-P)}{e^2} \tag{1}$$

Where: n = Sample size needed; Z = Confidence level (z-score); P = Standard deviation; and e = Margin error. The sample size estimator yielded 272.08. Thus, 270 sample sizes were used and 260 samples were retrieved for actual analysis.

Multicollinearity was tested using Variance Inflating Factor VIF (Geeks for Geeks, 2021). VIF is expressed in the regression model as;

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_k X_k \tag{2}$$

$$VIF = \frac{1}{1-R^2} \tag{3}$$

$$R^2 = \frac{\Sigma(y_{cal} - \bar{y})^2}{\Sigma(y_{given} - \bar{y})^2} \tag{4}$$

Decision rules;

If the value of VIF = 1; it indicates not correlated. Multicollinearity does not exist.

If the value of VIF ranged between 1 and 5; indicates relatively correlated. A level of multicollinearity exists.

If the value of VIF > 5; indicates extremely correlated. High levels of multicollinearity exist.

The inverse of VIF is known as Tolerance and expressed as;

$$TOL = \frac{1}{VIF} = (1 - R^2) \tag{5}$$

Hence, when R^2 is equal to zero ($R^2 = 0$), it implies that no collinearity exists, then the Tolerance is high (that's equal to 1).

State	Agricultural zone	LGA	Community	Population of the maize farmers	Number of respondents (sample)	Number of samples retrieved
Rivers	Ahoada	Etche	Igbodo	195	10	10
			Okehi	192	10	10
			Okomoko	182	10	9
	Degema	Abua/Odual	Otabha	118	10	9
			Abual	113	10	9
			Okana	124	10	10
	Eleme	Tai	Kporghor	153	10	10
			Gio	141	10	10
			Borobara	124	10	10

Source: Author's survey, 2023.

Table 3: summary of the study area sampling procedure (To be continued).

State	Agricultural zone	LGA	Community	Population of the maize farmers	Number of respondents (sample)	Number of samples retrieved
Bayelsa	Brass	Nembe	Ogbolomabiri	112	10	10
			Agrisaba	98	10	10
			Egbokabiriyai	93	10	9
	Yenagoa	Southern Ijaw	Korokosei	113	10	10
			Okolobiri	116	10	10
			Amasoma	125	10	10
	Sagbama	Ekeremor	Aleibiri	114	10	10
			Tantua	116	10	9
			Bolou-Orua	106	10	10
Akwa-Ibom	Abak	Etim Ekpo	Ikot Igwe	104	5	5
			Ikot-Obioma	102	5	5
			Ikot-Udobong	119	5	4
	Eket	Eastern Obolo	Iko	102	5	4
			Utu ikot Ukpong	103	5	4
			Elekpon	117	5	4
	Etinan	Etinan	Ikot Abasi	105	5	5
			Edem Ekpat	113	5	4
			Afaha Akpan Ekpo	102	5	5
	IkotEkpene	Essien Udim	Ikiot Ebak	116	5	5
			Utu Ekpenyong	97	5	5
			Odoro Ikot	106	5	5
	Oron	Mbo	Udini	104	5	5
			Ibete	96	5	5
			Ekiebong	112	5	4
	Uyo	Uruan	Idu Uruan	114	5	5
			Anakpa	102	5	5
			Ikot Akan	98	5	5
∑ 3	**12**	**12**	**36**	**4247**	**270**	**260**

Source: Author's survey, 2023.

Table 3: summary of the study area sampling procedure (Continuation).

Data collection

Data for this research were collected from primary and secondary sources. The primary data sources were collected by using questionnaires, interview schedules, and/ or group discussions as the case may demand. The primary data were obtained from the maize farmers that are still operating not from outdated or non-existing farms. Secondary sources include textbooks, journal publications, magazines, internet sources, and reports such as FAOSTAT.

Data analysis

Data for this research were analyzed by using descriptive and inferential statistics tools. The descriptive statistics instruments that were used for the study include frequency and percentages. The inferential statistics tools that were used are the correlation coefficient and multivariate probit (MVP) model.

Model specification

The Multivariate probit (MVP) model for climate change adaptation strategies as used by Ogunnaike et al (2021) and Purwanti et al (2022) expressed as;

$$Y(i=0,1,\ldots n) = \alpha_0 + \alpha_1 X_1 + \alpha_2 X_2 + \alpha X_3 + \alpha_4 X_4 + \alpha_5 X_5 + \alpha_6 X_6 + \alpha_7 X_7 + \alpha_8 X_8 + \alpha_9 X_9 + \alpha_{10} X_{10} + \alpha_{11} X_{11} + \alpha_{12} X_{12} + \alpha_{13} X_{13} + \alpha_{14} X_{14} \quad (6)$$

Where: Y_1 = Choice of using crop diversification ($Y = 1$); Y_2 = Change planting dates ($Y = 2$); Y_3 = Use of mixed farming – crop and rearing of livestock (Y = 3); Y_4 = Use of drought tolerant crop species ($Y = 4$); Y_5 = Use of improved crop species ($Y = 5$); and Y_6 = Off-farm job opportunities ($Y = 6$).

The independent variables are: X_1 = Age of the farmer (in years); X_2 = Gender (Dummy: male = 1; female = 0); X_3 = Marital status (Level: single = 1; married = 2; widow/widower = 3; divorced = 4); X_4 = Farming experience (in years); X_5 = Educational level (years spent in school); X_6 = Household size (in number); X_7 = Farm size (in ha); X_8 = Off-farm income (in Naira ₦); X_9 = Farm income (in Naira ₦); X10 = Access to information on climate change (Dummy: yes = 1; no = 0); X_{11} = Access to extension service (Dummy: yes = 1; no = 0); X_{12} = Access to credit/ finance (Dummy: yes = 1; no = 0); X_{13} = Farm/ crop insurance (Dummy: yes = 1; no = 0); and X_{14} = Farm association membership (Dummy: yes = 1; no = 0); α_0 = Constant; and α_1 - α_{14} = Coefficients of parameter estimated.

Partial eta squared in the MVP model is expressed as;

$$\delta_p^2 = \frac{SS_{effect}}{SS_{effect}+SS_{error}} \quad (7)$$

Where: δ_p^2 = Partial eta squared; and SS = Sum of squares.

Partial eta squared was employed to examine the effect of independent variable(s) on the dependent variable(s). Rule of thumb: δ_p^2 = 0.01; indicates a small effect; δ_p^2 = 0.06; indicates a medium effect; and δ_p^2 = 0.14; indicates a large effect.

Model justification

The MVP model is intended to examine scenarios involving multiple binary (yes/no) dependent variables. Unlike typical probit models, the MVP considers the potential that these outcomes are not independent, which is common in real-world data. One of the MVP model's main features is its ability to model the relationship between the error terms of the various binary outcomes (Greene, 2012). This is especially important when dealing with associated decisions or occurrences since disregarding these connections might result in skewed estimations and inaccurate inferences. The MVP model is ideal for complicated decision-making processes in which individuals or organizations make many, possibly connected choices at the same time. This makes it suitable for research in fields such as health economics, marketing, agriculture, and behavioral sciences, which are appropriate for this study (Belderbos, Carree, and Lokshin, 2004). The MVP model delivers more efficient and accurate parameter estimations than computing separate univariate probit models since the equations are estimated simultaneously (Cappellari, and Jenkins, 2003). This efficiency is derived by utilizing the covariance structure of the many outcomes. When there is endogeneity between various outcomes, the MVP paradigm may be modified to address these difficulties more effectively than simpler models. This increases the reliability and validity of the research findings. The MVP model is consistent with the study's theoretical framework, particularly if the research aims to investigate the drivers of several connected decisions or actions. Its theoretical base, which includes utility maximization and latent variable modelling, is sound. The MVP model (Belderbos et al., 2004) can be used to analyze joint decision-making processes in which maize farmers use multiple climate adaptation strategies at the same time, such as crop diversification, shifting planting dates, mixed farming, and the use of drought-tolerant crop species. These decisions are not independent; the choice to adopt one strategy may influence the likelihood of adopting another.

Results and discussion

From Table 4 it could be concluded that multicollinearity does not exist; which indicates that the variables were not correlated. Since the VIF values were greater than one (1) as well within the acceptable region and the Tolerance level (approximately equal to one, T = 1). Therefore, the models were accurate and appropriate o measure the data gathered.

Table 5 shows the climate change adaptation strategies techniques adopted the maize farmers in the study area. Majority (96.9%) of the maize famers actually adopted the use adaptation techniques as regards their maize farming. Majority (81.9%), (81.5%), (78.5%), (78.1%), (77.7%) and (68.1%) adopted the use of improved crop species, planting of drought tolerant crop species and changing in planting dates, crop diversification, mixed farming and off-farm job opportunities respectively. This implies that most of the maize farmers aimed to achieve optimum production and adopted several adaptation techniques to cope with the effects of climate change.

Table 6 depicts the correlation matrix of the relationships between various agricultural climate adaptation strategies adopted by maize farmers (crop diversification, changes in planting dates, mixed farming, planting of drought-tolerant crops, use of improved crop species, and off-farm job opportunities). Off-farm work possibilities and adoption of improved crop species (0.423)

Variable	Collinearity Statistics	
	Tolerance	VIF
Age (in years)	0.422	2.370
Gender	0.769	1.301
Marital status	0.501	1.997
Farming experience (in year)	0.563	1.778
Educational level (in year)	0.719	1.390
Household size (in number)	0.792	1.263
Maize farm size (in ha)	0.778	1.286
Average on-farm income in a year (in naira)	0.622	1.608
Average off-farm income in a year (in naira)	0.510	1.960
Access to information on climate change	0.724	1.382
Extension contact within a year	0.730	1.370
Access to credit/ finance facilities	0.598	1.671
Insure arable crop farm	0.694	1.440
Farmers association	0.682	1.466

Note: VIF means Variance Inflating Factor
Source: Field Survey, 2023.

Table 4: Collinearity diagnostics of multivariate probit (MVP) model used for climate change adaptation strategies analysis.

Variable	Frequency	Percentage
Used climate change adaptation strategies techniques		
Yes	252	96.9
No	8	3.1
Crop diversification		
Yes	203	78.1
No	57	21.9
Changing planting dates		
Yes	204	78.5
No	56	21.5
Mixed farming – crop and rearing of livestock		
Yes	202	77.7
No	58	22.3
Planting of drought tolerant crop species		
Yes	212	81.5
No	48	18.5
Use of improved crop species		
Yes	213	81.9
No	47	18.1
Off-farm job opportunities		
Yes	177	68.1
No	83	31.9
Total	260	100.0

Source: Field Survey, 2023.

Table 5: Climate change adaptation strategies and techniques adopted by the maize farmers.

are substantially positively connected, implying that maize farmer families participating in off-farm activities are more likely to adopt improved crop species, presumably due to increased money to invest in such technologies. Off-farm work possibilities and drought-tolerant crop planting

Variables	Crop diversification	Change planting dates	Mixed farming	Planting of drought-tolerant crop species	Use of improved crop species	Off-farm job opportunities
Crop diversification	1					
Change planting dates	0.288**	1				
Mixed farming	0.140*	0.146*	1			
Planting of drought-tolerant crop species	0.230**	0.142*	0.155*	1		
Use of improved crop species	0.307**	0.360**	0.069	0.290**	1	
Off-farm job opportunities	0.334**	0.186**	0.288**	0.373**	0.423**	1

Note: **, * means significant at 0.01 and 0.05 levels (2-tailed)
Source: Field Survey, 2023.

Table 6: Correlation matrix of the relationships between different adaptation strategies.

(0.373) have a substantial positive correlation, indicating that income diversification encourages farmers to invest in climate-resilient crops. Crop diversification and off-farm job opportunities (0.334) are positively correlated, implying that maize farmers with off-farm jobs may diversify crops to better manage maize production risks. The use of improved crop species and change in planting dates (0.360) are also positively correlated, indicating that maize farmers adopting improved crop species may adjust planting dates to maximize yield in changing climates.

Mixed farming with other techniques has smaller associations (ranging from 0.069 to 0.288); positive connections suggest that it complements other adaptation strategies. Mixed farming and the usage of enhanced crop species have a low correlation (0.069), which might indicate that mixed farming decisions are driven by reasons other than those driving the adoption of improved crop types. As a result, a multivariate probit (MVP) model was investigated to gain a better understanding of how different methods are implemented in tandem, taking into consideration their dependency.

Table 7 shows the result of the MVP model of climate change adaptation strategies adopted by the maize farmers. Bartlett's test of sphericity Loglikehood chi-squared tests of 176.936 was obtained and statistically significant at 1% level, null hypothesis that the residual covariance matrix is proportional to an identity matrix. The coefficient of multiple determination (R^2) shows that about 20.3% magnitude of climate change adaptation strategies adopted were explained by the independent variables included in the model, while Adjusted R^2 0.157 demonstrates the correct measurement of the model. Partial eta squared was used to measure the extent of the effect the independent variable(s) has on the dependent variable.

Crop diversification

From Table 7, age with a coefficient of -0.009 (p-value 0.010), is statistically significant at 1% and negatively impacts the probability of adopting crop diversification as climate change adaptation strategies. A unit increase in the age of the farmer could reduce the chances of adopting crop diversification by maize farmers by 0.9%, suggesting the adaptation age would enhance the chances of maize-based farmers adopting crop diversification as a climate change adaptation strategy. The negative coefficient for age shows that young maize farmers are possibly to diversify crops compared to the aged farmers, this could be a result of the young farmers being opened to innovation and curiosity about trying new adaptation strategies to enhance their maize production. This result is in agreement with Enimu and Onome (2018) who found out among farmers in Delta State that, regardless of the older farmers being aware of innovations, they are not willing to attempt new adaptation strategies. A partial eta squared of 0.027 was obtained, which indicates a small effect on the use of crop diversification as a climate change adaptation strategy. Marital status with a coefficient of 0.183 (p-value 0.004), is statistically significant at 1% and positively impacts the probability of adopting crop diversification as climate change adaptation strategies. A unit increase in the marital status of the farmer could increase the chances of adopting crop diversification by maize farmers by 18.3%, suggesting the adaptation marital status would increase the chances of maize-based farmers adopting crop diversification as climate change adaptation strategies. A partial eta squared of 0.003 was obtained, which indicates a small effect on the use of crop diversification as a climate change adaptation strategy. Household size with a coefficient of -0.031 (p-value 0.025), is statistically significant at 5% and negatively impacts

Variables	Crop diversification	Changing planting dates	Mixed farming	Planting of drought-tolerant crop species	Use improved crop species	Off-farm job opportunities
Intercept	0.408**	0.091	0.533***	0.405**	0.354*	0.535**
	(0.192)[0.018]	(0.193)[0.001]	(0.200)[0.028]	(0.195)[0.017]	(0.187)[0.014]	(0.240)[0.020]
Age	-0.009***	0.001	-0.010***	-0.003	-0.005	-0.010**
	(0.003)[0.027]	(0.003)[0.000]	(0.004)[0.031]	(0.003)[0.003]	(0.003)[0.009]	(0.004)[0.022]
Gender	0.053	-0.013	-0.144***	0.049	0.101**	0.033
	(0.053)[0.004]	(0.054)[0.000]	(0.056)[0.027]	(0.054)[0.003]	(0.052)[0.015]	(0.067)[0.001]
Marital	0.183***	-0.023	0.154**	0.042	0.043	0.087
	(0.004)[0.003]	(0.064)[0.001]	(0.066)[0.022]	(0.064)[0.002]	(0.062)[0.002]	(0.079)[0.005]
FrmExp	0.003	-0.001	0.004	0.005**	0.002	0.005*
	(0.002)[0.006]	(0.002)[0.000]	(0.002)[0.009]	(0.002)[0.017]	(0.002)[0.003]	(0.003)[0.013]
EduLev	-0.001	0.012**	-0.003	-0.006	0.001	-0.009
	(0.005)[0.000]	(0.005)[0.021]	(0.005)[0.002]	(0.005)[0.005]	(0.005)[0.000]	(0.006)[0.008]
Household size	-0.031**	0.015	0.011	-0.021*	-0.009	0.013
	(0.014)[0.021]	(0.014)[0.005]	(0.014)[0.003]	(0.014)[0.010]	(0.013)[0.002]	(0.006)[0.002]
MzFrmSiz	0.062***	0.038	0.016	-0.003	0.014	-0.060*
	(0.027)[0.022]	(0.027)[0.008]	(0.028)[0.001]	(0.027)[0.000]	(0.026)[0.001]	(0.033)[0.013]
OnFrmInc	1.5E-7	1.8E-7	-9.9E-8	-5.4E-8	-9.9E-9	-1.3E-7
	(0.001)0.003]	(0.001)[0.005]	(0.001)[0.001]	(0.001)[0.000]	(0.001)[0.000]	(2.1E-7)[0.001]
OffFrmInc	-4.6E-8	2.3E-9	-2.2E-7**	1.3E-7	1.6E-7*	1.2E-7
	(0.001)[0.001]	(0.001)[0.000]	(0.001)[0.015]	(0.001)[0.006]	(0.001)[0.008]	(1.4E-7)[0.003]
InfCC	0.555***	0.404***	0.374***	0.540***	0.542***	0.376**
	(0.112)[0.092]	(0.113)[0.050]	0.117)[0.041]	(0.114)[0.085]	(0.109)[0.092]	(0.140)[0.029]
ExtCont	0.035	0.148**	-0.048	-0.007	-0.054	-0.044
	(0.061)[0.001]	(0.062)[0.023]	(0.064)[0.002]	(0.062)[0.000]	(0.060)[0.003]	(0.077)[0.001]
AccesCred	-0.072	0.113*	0.111*	-0.097*	0.003	-0.007
	(0.059)[0.006]	(0.060)[0.014]	(0.062)[0.013]	(0.61)[0.010]	(0.058)[0.000]	(0.075)[0.000]
InsurFarm	0.214***	-0.066	0.114	0.246***	0.116	0.180*
	(0.082)[0.027]	(0.083)[0.003]	(0.086)[0.007]	(0.084)[0.034]	(0.080)[0.008]	(0.103)[0.012]
FrmAss	0.021	-0.009	0-.033	0.055	0.122**	0.129
	(0.065)[0.000]	(0.066)[0.000]	(0.068)[0.001]	(0.067)[0.003]	(0.064)[0.015]	(0.082)[0.010]

Note: ***, **, * means significant at 1%, 5%, and 10% respectively; the first figures are the betas, the bracket "( )" is the standard errors, and the parenthesis, "[ ]" is the partial eta squared; 0.01, 0.06 and 0.14 indicate small, medium and large effect of partial eta squared respectively; Bartlett's test of sphericity: Loglikehood Chi-squared = 176.936 (0.000), R^2 = 0.203, Adjusted R^2 = 0.157; Sample size = 260

Source: Field Survey, 2023.

Table 7: Parameter estimates of the Multivariate Probit (MVP) model of maize (Zea mays) farmers showing climate change adaptation strategies adopted in the study area and their determinants.

the probability of adopting crop diversification as a climate change adaptation strategy. An increase in the household size of the farmer could reduce the chances of adopting crop diversification by maize farmers in adopting crop diversification as climate change adaptation strategies. The negative coefficient of the household size implies that maize farmers with less household size are more likely to adopt crop diversification to cope with the effects of climate change. A partial eta squared of 0.021 was obtained, which indicates a small effect on the use of crop diversification as a climate change adaptation strategy. Maize farm size with a coefficient of 0.062 (p-value 0.019), is statistically significant at 5% and positively impacts the probability of adopting crop diversification as climate change adaptation strategies. An increase in the maize farm size of the farmer could increase the chances of adopting crop diversification by maize farmers in adopting crop diversification as climate change adaptation strategies. This implies that maize farmers with large farm sizes could easily adopt crop diversification as a way of minimizing the effect of climate change on their production. A partial eta squared of 0.022 was obtained, which indicates a small effect on the use of crop diversification as a climate change adaptation strategy. Access to information on climate change with a coefficient of 0.555 (p-value 0.000), is statistically significant at 1% and positively impacts the probability of adopting crop diversification as climate change adaptation strategies. A unit increase in access to information on climate change could increase the chances of adopting crop diversification by maize farmers by 55.5%, suggesting that adaptation access to information on climate change would improve the chances of maize-based farmers adopting crop diversification as climate change adaptation strategies. This implies that timely access to information on climate change could increase the rate of climate change adaptation strategies through crop diversification. The maize farmer that received information earlier could probably adopt the strategy than the farmers that may likely get the information late. This finding is in agreement with Gemeda, Korecha, and Garedew (2023) who found out that, access to climate information is correlated with crop diversification in Ethiopia. A partial eta squared of 0.092 was obtained, which indicates a medium effect on the use of crop diversification as a climate change adaptation strategy. Awareness of crop insurance with a coefficient of 0.214 (p-value 0.010), is statistically significant at 1% and positively impacts the probability of adopting crop diversification as climate change adaptation strategies. A unit increase in awareness of crop insurance could increase the chances of adopting crop diversification by maize farmers by 21.4%, suggesting that adaptation awareness of crop insurance would improve the chances of maize-based farmers adopting crop diversification as climate change adaptation strategy. This implies transferring the losses that may be encountered in maize production is possible through insurance companies. A partial eta squared of 0.029 was obtained, which indicates a small effect on the use of crop diversification as a climate change adaptation strategy. Therefore, the results of the multivariate probit (MVP) model provide sufficient indication for the simultaneous and codependent adaptation choices.

Changing planting dates

From Table 7, educational level with a coefficient of 0.012 (p-value 0.023), is statistically significant at 5% and positively impacts the probability of adopting changing planting dates as climate change adaptation strategies. An increase in years of the educational level of the farmer could increase the chances of adopting changing planting dates by maize farmers in adopting changing planting dates as climate change adaptation strategies. This implies that the more years the maize farmers spend to attain the level of education is very significant in studying and changing the planting date of maize for efficient productivity. This finding is not consistent with the result of Mwinkom, Damnyag, Abugre, and Alhassan (2021) who obtained a negative coefficient in their studies among farmers in North-Western Ghana. A partial eta squared of 0.021 was obtained, which indicates a small effect on the use of changing planting dates as a climate change adaptation strategy. Access to information on climate change with a coefficient of 0.404 (p-value 0.000), is statistically significant at 1% and positively impacts the probability of adopting change planting dates as climate change adaptation strategies. A unit increase in access to information on climate change could increase the chances of adopting changing planting dates by maize farmers by 40.4%, suggesting that adaptation access to information on climate change would improve the chances of maize-based farmers adopting changing planting dates as climate change adaptation strategies. This finding agrees with Mwinkom et al (2021) who reported that information on climate change influences the changes in planting time in Ghana. A partial eta squared of 0.050 was obtained, which indicates a small effect on the use of changing planting dates as a climate change adaptation strategy. Agricultural extension contacts with a coefficient of 0.148 (p-value 0.017), are statistically significant at 5% and positively impact the probability of adopting changing planting dates as climate change adaptation strategies. An increase in agricultural extension contacts of the farmer could increase the chances of adopting changing planting dates by maize farmers in adopting changing planting dates as climate change adaptation strategies. This implies that agricultural extension services offer very vital and accurate information on climate change and are capable of providing good agricultural and management practices to cope with climate change. Hence, farmers with better contact with the extension have a greater chance to alter planting dates for maximum yields even amid climate challenges. This finding is in agreement with Nhemachena, Hassan, and Chakwizira (2014) who noted that increasing access to free agricultural extension services delivery to farmers has the prospective to considerably enhance farmers' awareness of changes in climatic factors, and in addition adaptation strategies to adopt in response to climate changes hazards. A partial eta squared of 0.023 was obtained, which indicates a small effect on the use of changing planting as a climate change adaptation strategy. The multivariate probit (MVP) model results, consequently, afford appropriate substantiation for simultaneous adaptation choices.

Mixed farming – crop and rearing of livestock

From Table 7, age with a coefficient of -0.010 (p-value 0.006), is statistically significant at 1% and negatively impacts the probability of adopting mixed farming – crop and rearing of livestock as climate change adaptation strategies. A unit increase in the age of the farmer could reduce the chances of adopting mixed farming – crops, and rearing of livestock by maize farmers by 1%, suggesting the adaptation age would enhance the chances of maize-based farmers adopting mixed farming – crop and rearing of livestock as climate change adaptation strategies. This implies that mixed farming strategies are better capable of coping with the climate change factors through enterprise different changes in management strategies; this is possible because the younger farmers can carry out a lot of activities at or almost the same time. This finding is in agreement with Nhemachena et al (2014) who reported that mixed farming strategies are already adopted and the farmers have several alternative crops and livestock choices that could guarantee that in case one choice fails as a result of climate change the other would do well even if there are variations in climatic factors. A partial eta squared of 0.031 was obtained, which indicates a small effect on the use of mixed farming as a climate change adaptation strategy. Gender with a coefficient of -0.144 (p-value 0.010), is statistically significant at 1% and negatively impacts the probability of adopting mixed farming – crop, and rearing of livestock as climate change adaptation strategies. This implies that female maize farmers could reduce the chances of adopting mixed farming – crops, and rearing livestock, suggesting the adaptation gender would enhance the chances of maize-based farmers adopting mixed farming – crops, and rearing livestock as climate change adaptation strategies. This implies that female maize farmers may likely be affected. This finding agrees with Nyadzi, Werners, Biesbroek, Long, Franssen, and Ludwig (2019) who found that male farmers had a higher possibility of adopting climate adaptation strategies than their female farmer counterparts. A partial eta squared of 0.027 was obtained, which indicates a small effect on the use of mixed farming as a climate change adaptation strategy. Marital status with a coefficient of 0.154 (p-value 0.020), is statistically significant at 5% and positively impacts the probability of adopting mixed farming – crop and rearing of livestock as climate change adaptation strategies. An increase in the marital status of the farmer could increase the chances of adopting mixed farming – crop, and rearing of livestock by maize farmers in adopting mixed farming – crop and rearing of livestock as climate change adaptation strategies. This implies that married maize farmers could adopt mixed farming than their single farmers' counterparts. A partial eta squared of 0.022 was obtained, which indicates a small effect on the use of mixed farming as a climate change adaptation strategy. Off-farm incomes with a coefficient of -2.219E-7 (p-value 0.058), are statistically significant at 5% and negatively impact the probability of adopting mixed farming – crop and rearing of livestock as climate change adaptation strategies. An increase in off-farm incomes of the farmer could reduce the chances of adopting mixed farming – crop, and rearing of livestock by maize farmers in adopting mixed farming – crop, and rearing of livestock as climate change adaptation strategies. This implies that the maize farmers could spend their off-farm income to adapt to climate change adaptation strategies. A partial eta squared of 0.015 was obtained, which indicates a small effect on the use of mixed farming as a climate change adaptation strategy. Access to information on climate change with a coefficient of 0.374 (p-value 0.002), is statistically significant at 1% and positively impacts the probability of adopting mixed farming – crop, and rearing of livestock as climate change adaptation strategies. A unit increase in access to information on climate change of the farmer could increase the chances of adopting mixed farming – crop, and rearing of livestock by maize farmers by 37.4%, suggesting the adaptation access to information on climate change would enhance the chances of maize-based farmers adopting mixed farming – crop and rearing of livestock as climate change adaptation strategies. This implies that access to information on climate change is very crucial for productive adaptation. A partial eta squared of 0.041 was obtained, which indicates a small effect on the use of mixed farming as a climate change adaptation strategy. The multivariate probit (MVP) model results, consequently, provide appropriate substantiation for simultaneous adaptation choices.

Planting of drought-tolerant crop species

From Table 7, farming experience with a coefficient of 0.005 (p-value 0.039), is statistically significant at 5% and positively impacts the probability of adopting planting of drought tolerant crop species as climate change adaptation strategies. An increase in the farming experience of the farmer could increase the chances of adopting the planting of drought-tolerant crop species by maize farmers in adopting crop diversification as a climate change adaptation strategy. This implies that an increase in the farming experience of maize farmers could lead to more understanding of plant drought-tolerant crop species. A partial eta squared of 0.017 was obtained, which indicates a small effect on the use of drought-tolerant crop species as climate change adaptation strategies. Access to information on climate change with a coefficient of 0.540 (p-value 0.000), is statistically significant at 1% and positively impacts the probability of adopting access to information on climate change as climate change adaptation strategies. An increase in the farming experience of the farmer could increase the chances of adopting access to information on climate change by maize farmers in adopting crop diversification as climate change adaptation strategies. This implies that access to information on climate change is very crucial for productive adaptation. A partial eta squared of 0.085 was obtained, which indicates a medium effect on the use of planting drought-tolerant crop species as climate change adaptation strategies. Awareness of farm/ crop insurance with a coefficient of 0.246 (p-value 0.004), is statistically significant at 1% and positively impacts the probability of adopting planting of drought-tolerant crop species as climate change adaptation strategies. An increase in awareness of farm/ crop insurance of the farmer could increase the chances of adopting planting of drought-tolerant crop species by maize farmers in adopting crop diversification as a climate change adaptation strategy. This implies transferring the losses that may be encountered in maize production is possible through insurance companies. A partial eta squared of 0.034 was obtained, which indicates a small effect on the use of planting of drought-tolerant crop species as a climate change adaptation strategy. The multivariate probit (MVP) model results, consequently, provide appropriate substantiation for simultaneous adaptation choices.

Use of improved crop species

From Table 7, gender with a coefficient of 0.101 (p-value 0.054), is statistically significant at 5% and positively impacts the probability of adopting improved crop species as climate change adaptation strategies. This implies that both genders (male and female) can adopt improved crop species for planting. A partial eta squared of 0.015 was obtained, which indicates a small effect on the use of planting of improved crop species as climate change adaptation strategies. Access to information on climate change with a coefficient of 0.542 (p-value 0.000), is statistically significant at 1% and positively impacts the probability of adopting planting of improved crop species as climate change adaptation strategies. A unit increase in access to information on climate change of the farmer could increase the chances of adopting planting of improved crop species by maize farmers by 54.2%, suggesting the adaptation of access to information on climate change would improve the chances of maize-based farmers in adopting crop diversification as climate change adaptation strategies. This implies that access to information on climate change is very crucial for productive adaptation. A partial eta squared of 0.092 was obtained, which indicates a medium effect on the use of improved crop species as climate change adaptation strategies. Farmers association with a coefficient of 0.122 (p-value 0.056), is statistically significant at 5% and positively impacts the probability of adopting improved crop species as climate change adaptation strategies. An increase in farmers' associations of the farmer could increase the chances of adopting improved crop species by maize farmers adopting improved crop species as climate change adaptation strategies. This implies that farmers' membership in association could aid the rate of adaptation to climate change hazards. A partial eta squared of 0.015 was obtained, which indicates a medium effect on the use of improved crop species as climate change adaptation strategies. The multivariate probit (MVP) model results, consequently, afford appropriate substantiation for simultaneous adaptation choices.

Off-farm job opportunities

From Table 7, age with a coefficient of -0.010 (p-value 0.019), is statistically significant at 5% and negatively impacts the probability of adopting off-farm job opportunities as climate change adaptation strategies. An increase in the age of the farmer could reduce the chances of adopting off-farm job opportunities by maize farmers in adopting off-farm job opportunities as climate change adaptation strategies. This implies that the younger maize farmers could engage in multiple activities to cope with climate change effects. A partial eta squared of 0.022 was obtained, which indicates a small effect on the use of off-farm job opportunities as climate change adaptation strategies. Access to information on climate change with a coefficient of 0.376 (p-value 0.008), is statistically significant at 1% and positively impacts the probability of adopting off-farm job opportunities as climate change adaptation strategies. A unit increase in access to information on climate change of the farmer could increase the chances of adopting off-farm job opportunities for maize farmers by 37.6%, suggesting the adaptation of off-farm job opportunities would enhance the chances of maize-based farmers in adopting off-farm job opportunities as climate change adaptation strategies. This implies that access to information on climate change is very crucial for productive adaptation. A partial eta squared of 0.029 was obtained, which indicates a medium effect on the use of off-farm job opportunities as climate change adaptation strategies. The multivariate probit (MVP) model results, consequently, provide appropriate substantiation for simultaneous adaptation choices.

Conclusion

This research examined the analysis of determinants of maize farmers' adaptation strategies to climate change in South-South Nigeria. The result of the Variance Inflating Factor (VIF) and Tolerance level revealed that multicollinearity does not exist. The result shows that the majority of the maize farmers adopted the use of improved crop species, planting of drought tolerant crop species and changing in planting dates, crop diversification, mixed farming, and off-farm job opportunities as a means of adaptation strategies to climate change impacts. The multivariate probit (MVP) model results show that among all determinants, access to information on climate change was the most important influencing factor that enabled farmers to adopt different adaptation strategies because it was statistically significant in all the dependent variables used in the analyses.

Analyzing the determinants of adaptation strategies to climate change can aid the decision-makers and farmers to take additional mediations against the negative impacts of climate change. Declining agricultural yields and food insecurity caused by climate change continue to be the major concerns affecting farming communities' nutritional needs and food preferences. The research, therefore recommends that:

The government and NGOs should design a viable strategy to address the existing barriers to climate change adaptation strategies in the study area. Eliminating the existing barriers while supporting the farming communities with technical skills based on state-of-the-art modern science can enhance the adaptive capacity of vulnerable maize farmers to climate change.

A farmer's understanding of the impact of climate change is a fundamental requirement for designing adaptation strategies. Therefore, maize farmers should be constantly enlightened on the danger associated with climate change. This understanding of the impacts of climate change on maize farming could help policy-makers to develop appropriate adaptation and mitigation strategies.

Furthermore, institutional collaboration among the tiers of institutions is needed to improve access to credit/ finance facilities, avail affordable farm inputs (like a hybrid of maize seed), adequate extension service delivery, eliminate the risk of maize pests and disease, and provide necessary and timely information for the maize farmers.

Acknowledgments

This research was supported by funding from the Nigerian Conservation Foundation (NCF) under the Chief S.L. Edu Ph.D. research grant.

Corresponding author:
Adeyinka Richard Aroyehun
Department of Agricultural Economics and Agribusiness Management,
Faculty of Agriculture, University of Port Harcourt
East/West Road, PMB 5323 Choba, Rivers State, Nigeria
Email: +2347065528824, E-mail: aroyehun_adeyinka@unipoert.edu.ng

References

[1] Abbass, K., Qasim, M. Z., Song, H., Murshed, M., Mahmood, H. and Younis, I. (2022) "A review of the global climate change impacts, adaptation, and sustainable mitigation measures", *Environmental Science and Pollution Research*, Vol. 29, pp. 42539–42559. E-ISSN 1614-7499. DOI 10.1007/s11356-022-19718-6.

[2] Adeagbo, O. A., Ojo, T. O. and Adetoro, A. A. (2021) "Understanding the determinants of climate change adaptation strategies among smallholder maize farmers in South-west, Nigeria", *Heliyon*, Vol.7 , No. 2. ISSN 2405-8440. DOI 10.1016/j.heliyon.2021.e06231.

[3] Adejuwon, J. O. (2005) "Food crop production in Nigeria: I. Present effects of climate variability", *Climate Research*, Vol. 30, No. 1, pp. 53-60. ISSN 0936-577X. DOI 10.3354/cr030053.

[4] Aderinoye-Abdulwahab, S. A. and Abdulbaki, T. A. (2021) "Climate change adaptation strategies among cereal farmers in Kwara State, Nigeria", In: Filho, W. L. et al. (eds.) "*African Handbook of Climate Change Adaptation*", pp. 509-522. ISBN 978-3-030-42091-8. DOI 10.1007/978-3-030-45106-6_228.

[5] Akinnagbe, O. M. and Irohibe, I. J. (2014) "Agricultural adaptation strategies to climate change impacts in Africa: A review", *Bangladesh Journal of Agricultural Research*, Vol. 39, No. 3, pp. 407-418. E-ISSN 2408-8293, ISSN 0258-7122. DOI 10.3329/bjar.v39i3.21984.

[6] Akpodiogaga-a, P. and Odjugo, O. (2010) "General overview of climate change impacts in Nigeria", *Journal of Human Ecology*, Vol. 29, pp. 47-55. E-ISSN 2456-6608, ISSN 0970-9274. DOI 10.1080/09709274.2010.11906248.

[7] Arokoyu, S. B. and Weje, I. I. (2015) "Spatial distribution of health facilities in the South-South, Nigeria", *Journal of Science and Technology*, Vol. 5, No. 2, pp. 61-67. ISSN 2225-7217.

[8] Aroyehun, A. R. (2023) "Impacts of climate change and population growth on food security in Nigeria", *Black Sea Journal of Agriculture*, Vol. 6, No. 3, pp. 232-240. E-ISSN 2618-6578. DOI 10.47115/bsagriculture.1232578.

[9] Baumann, F. (2018) "The systemic challenge of global heating", *International Politics Reviews*, Vol. 6, No. 38, pp. 134-144. DOI 10.1057/s41312-018-0065-5.

[10] Bedeke, S. B., Vanhove, W., Gezahegn, M., Natarajan, K. and Van Damme, P. (2019) "Adoption of climate change adaptation strategies by maize-dependent smallholders in Ethiopia", *NJAS-Wageningen Journal of Life Sciences*, Vol. 88, pp. 96-104. ISSN 1573-5214. DOI 10.1016/j.njas.2018.09.001.

[11] Belderbos, R., Carree, M. and Lokshin, B. (2004) "Cooperative R&D and firm performance", *Research Policy*, Vol. 33, No. 10, pp. 1477-1492. E-ISSN 2329-3292, ISSN 2329-3284. DOI 10.1016/j.respol.2004.07.003.

[12] Bours, D., McGinn, C. and Pringle, P. (2014) "The theory of change approach to climate change adaptation programming", *Guidance for M&E of climate change interventions,* SEA Change CoP, Phnom Penh and UKCIP, Oxford. pp. 1-10. [Online]. Available: https://www.ukcip.org.uk/wp-content/PDFs/MandE-Guidance-Note3.pdf [Accessed: March. 2, 2023]. DOI 10.13140/RG.2.1.3772.9045.

[13] Cappellari, L. and Jenkins, S. P. (2003) "Multivariate probit regression using simulated maximum likelihood", *The Stata Journal*, Vol. 3, No. 3, pp. 278-294. E-ISSN 1536-8734. ISSN 1536-867X. DOI 10.1177/1536867X0300300305.

[14] Dasgupta, S. and Robinson, E. J. Z. (2022) "Attributing changes in food insecurity to a changing climate", *Scientific Reports,* Vol. 12, p. 4709. ISSN 2045-2322. DOI 10.1038/s41598-022-08696-x.

[15] Eisenack, K. and Stecker, R. (2011) "An action theory of adaptation to climate change", Earth System Governance Working Paper No. 13. Lund and Amsterdam: Earth System Governance Project. [Online]. Available: https://www.earthsystemgovernance.org/publication/an-action-theory-of-adaptation-to-climate-change/[Accessed: March. 2, 2023].

[16] Enimu, S. and Onome, G. E. (2018) "Determinants of climate change adaptation strategies among farm households in Delta State, Nigeria", *Current Investigations in Agriculture and Current Research*, Vol. 5, No. 3, pp. 663-668. E-ISSN 2637-4676. DOI 10.32474/CIACR.2018.05.000213.

[17] Federal Ministry of Agriculture and Rural Development (FMARD) (2014) "*National Agricultural Resilience Framework (NARF)*", Abuja: FMARD. [Online]. Available: https://policyvault.africa/wp-content/uploads/policy/NGA144.pdf. [Accessed: Jan. 17, 2023].

[18] Federal Ministry of Agriculture and Rural Development FMARD (2016)"*Agricultural Promotion Policy APP (2016-2020): Policy and strategy document*", Abuja, Nigeria. [Online]. Available: https://nssp.ifpri.info/files/2017/12/2016-Nigeria-Agric-Sector-Policy-Roadmap_June-15-2016_Final.pdf. [Accessed: Jan. 17, 2023].

[19] Federal Ministry of Environment (2011) "*National Adaptation Strategy and Plan of Action on Climate Change for Nigeria (NASPA-CCN)*", Abuja: Federal Ministry of Environment. [Online]. Available: https://www.fao.org/faolex/results/details/en/c/LEX-FAOC211219/. [Accessed: Jan. 17, 2023].

[20] Food and Agriculture Organization FAO (2013) "*Climate-Smart Agriculture sourcebook*", Rome. [Online]. Available: https://www.fao.org/3/i3325e/i3325e.pdf. [Accessed: Dec. 20, 2022].

[21] Food and Agriculture Organization FAO (2016) "T*he state of food and agriculture: Climate change, agriculture and food security*", Rome, FAO. [Online]. Available: https://openknowledge.fao.org/server/api/core/bitstreams/07bc7c6e-72e5-488d-b2f7-3c1499d098fb/content. [Accessed: Dec. 20, 2022].

[22] Gebrechorkos, S. H., Hulsmann, S. and Bernhofer, C. (2020) "Analysis of climate variability and drought in East Africa using high resolution climate data products", *Global Planet Change*, Vol. 186, p. 103130. ISSN 0921-8181. DOI 10.1016/j.gloplacha.2020.103130.

[23] GeeksforGeeks (2021) "*Test of multicollinearity*", [Online]. Available: https://www.geeksforgeeks.org/test-of-multicollinearity/. [Accessed: March 2, 2023].

[24] Gemeda, D. O., Korecha, D. and Garedew, W. (2023) "Determinants of climate change adaptation strategies and existing barriers in Southwestern parts of Ethiopia", *Climate Services*, Vol. 30, pp. 1-12. ISSN 2405-8807. DOI 10.1016/j.cliser.2023.100376.

[25] Greene, W. H. (2012) "*Econometric analysis*", 7th ed., Pearson Education. ISBN 978-0-13-139538-1.

[26] Ibrahim, H. D. (2020) "*Harnessing the non-oil resource potentials of the South-South zone for value addition, industrial development, and export*". [Online]. Available: https://neximbank.com.ng/wp-content/uploads/2020/02/South-South-Zone-for-Value-Addition.pdf. [Accessed: March. 5, 2023].

[27] Ifeanyi-Obi, C. C., Etuk, U. R. and Jike-Wai, O. (2012) "Climate change, effects and adaptation strategies; implications for agricultural extension system in Nigeria", *Greener Journal of Agricultural Sciences*, Vol.2, No. 2, pp. 53-60. ISSN 2276-7770. DOI 10.15580/GJAS.2013.3.1234.

[28] Intergovernmental Panel on Climate Change. IPCC (2019) "*Climate change and land*", An IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems" [Shukla, P. R., Skea, J., Calvo Buendia, E., Masson-Delmotte, V., Portner, H. O., Roberts, D. C., Zhai, P., Slade, R., Connors, S., van Diemen, R., Ferrat, M., Haughey, E., Luz, S., Neogi, S., Pathak, M., Petzold, J., Portugal Pereira, J., Vyas, P., Huntley, E., Kissick, K., Belkacemi, M., Malley, J. (eds.)]. [Online]. Available: https://www.ipcc.ch/site/assets/uploads/2019/11/SRCCL-Full-Report-Compiled-191128.pdf. [Accessed: Nov. 13, 2022]. DOI 10.1017/9781009157988.

[29] Intergovernmental Panel on Climate Change IPCC (2021) "*Climate Change 2021: The Physical Science Basis*", IPCC Sixth Assessment Report, The Working Group I contribution to the Sixth Assessment Report addresses the most up-to-date physical understanding of the climate system and climate change, bringing together the latest advances in climate science. [Masson-Delmotte, V., Zhai, P., Pirani, A., Connors, S. L., Peab, C., Berger, S., Caud, N., Chen, Y., Goldfarb, L., Gomis, M.I., Huabng, M., Leitzell, K., Lonnoy, E., Mattews, J.B.R., Maycock, T. K., Waterfield, T., Yelekci, O., Yu, R., Zhou, B (eds.)]. [Online]. Available: https://www.ipcc.ch/report/ar6/wg1/. [Accessed: Nov. 13, 2022].

[30] International Fund for Agricultural Development IFAD (2020) "*Mid-term review of IFAD's adaptation for smallholder agriculture programme final report*". [Online]. Available: https://www.ifad.org/documents/d/new-ifad.org/itad_asap_midreport-pdf. [Accessed: Nov. 13, 2022]. DOI 10.1017/9781009157896

[31] Jaidka, M., Bathla, S. and Kaur, R. (2019) "Improved technologies for higher maize production", In: "*Maize - production and use*", Hossain, A. (Ed.). IntechOpen, pp. 1-21. ISBN 978-1-83880-261-5, E-ISBN 978-1-78984-621-8. DOI 10.5772/intechopen.88997.

[32] Jian, W. and Rehman, A. (2016) "*Risk management in agriculture: Theories and methods*", Science Publishing Group. [Online]. Available: https://www.researchgate.net/publication/316147274_Risk_Management_in_Agricultural-_Theories_and_Methods. [Accessed: Nov. 13, 2022].

[33] Kabira, M. J., Alauddinb, M. and Crimp, C. (2017) "Farm-level adaptation to climate change in Western Bangladesh: An analysis of adaptation dynamics, profitability and risks", *Land Use Policy*, Vol. 64, pp. 212-224. ISSN 0264-8377. DOI 10.1016/j.landusepol.2017.02.026.

[34] Kamara, A. Y., Kamai, N., Omoigui, L. O., Togola, A., Ekeleme, F. and Onyibe, J. E. (2020) "*Guide to maize production in northern Nigeria*", lbadan, Nigeria. ISBN: 00000000000. [Online]. Available: https://www.iita.org/wp-content/uploads/2020/07/Guide-to-Maize-Production-in-Northern-Nigeria.pdf [Accessed: Nov. 13, 2022].

[35] Kibuacha, F. (2021) "*How to determine sample size for a research study*". [Online]. Available: https://www.geopoll.com/blog/sample-size-research/. [Accessed: March. 5, 2023].

[36] Kumar, L., Chhogyel, N., Gopalakrishnan, T., Hasan, M. K., Jayasinghe, S. L., Kariyawasam, C. S., Kogo, B. K. and Ratnayke, S. (2022) "Climate change and future of agri-food production", In: *Future Foods: Global Trends, Opportunities, and Sustainability Challenges*, pp. 49-79. ISBN 978-0-323-91001-9, DOI 10.1016/B978-0-323-91001-9.00009-8.

[37] Mboera, L., Mayala, B., Kweka, E. and Mazigo, H. (2012) "Impact of climate change on human health and health systems in Tanzania: A review", *Tanzania Journal of Health Research*, Vol. 13, No. 5, pp. 1-23. E-ISSN 1821-9241, ISSN 1821-6404. DOI 10.4314/thrb.v13i5.10.

[38] Mequannt, M., Fikadu, Y., Mebrahtu, H. and Filmon, T. (2020) "Farmers' choices and factors affecting adoption of climate change adaptation strategies: Evidence from north-western Ethiopia", *Heliyon*, Vol. 6, No. 4, p. e03867, pp. 1-10. E-ISSN 2405-8440. DOI 10.1016/j.heliyon.2020.e03867.

[39] Mercer, J. (2020) "Disaster risk reduction or climate change adaptation: Are we reinventing the wheel?", *Journal of International Development*, Vol. 22, No. 2, pp. 247-264. E-ISSN 1099-1328, ISSN 0954-1748. DOI 10.1002/jid.1677.

[40] Mwinkom, F. X. K., Damnyag, L., Abugre, S. and Alhassan, S. I. (2021) "Factors influencing climate change adaptation strategies in North-Western Ghana: Evidence of farmers in the Black Volta Basin in Upper West region", *Springer Nature Journal of Applied Sciences*, Vol. 3, No. 548. E-ISSN 3004-9261. DOI 10.1007/s42452-021-04503-w.

[41] National Population Commission. NPC (2020) "*Nigeria population projections and demographic indicators, National and States*". ISBN 978-978-983-000-8. [Online]. Available: https://factcheckhub.com/wp-content/uploads/2022/07/national-population-commission-Projection_2022.pdf [Accessed: March. 5, 2023].

[42] Nhemachena, C. Hassan, R. and Chakwizira, J. (2014) "Analysis of determinants of farm-level adaptation measures to climate change in Southern Africa", *Journal of Development and Agricultural Economics*, Vol. 6, No. 5, pp. 232-241. ISSN 2006-9774. DOI 10.5897/JDAE12.0441.

[43] Niger Delta Development Commission (NDDC) (2019) "*Niger Delta Needs Integrated Strategies for Safe Environment –NDDC Director*", Port Harcourt: NDDC. [Online]. Available: https://www.nddc.gov.ng/News/NewsDetails/2531. [Accessed: March. 5, 2023].

[44] Nigerian Meteorological Agency (NIMET) (2022) "*Extreme weather report*", Abuja. [Online]. Available: https://ngflibrary.org.ng/cgi-bin/koha/opac-detail.pl?biblionumber=20200&query_desc=au%3ANigerian%20Meteorological%20Agency [Accessed: Feb. 15, 2023].

[45] Nyadzi, E., Werners, E. S., Biesbroek, R., Long, P. H., Franssen, W. and Ludwig, F. (2019) "Verification of seasonal climate forecast toward hydroclimatic information needs of rice farmers in Northern Ghana", *Weather, Climate, and Society*, Vol. 11, No. 1, pp. 127-142. E-ISSN 1948-8335, ISSN 1948-8327. DOI 10.1175/WCAS-D-17-0137.1.

[46] Ogbodo, S. O. (2022) "Niger Delta Development Commission (N.D.D.C.) and provision of infrastructure in Niger Delta Region, 2009- 2022", *Newport International Journal of Research in Education*, Vol. 4, No. 2, pp. 34-56. E-ISSN 2992-5509, ISSN 2992-6092. DOI 10.59298/NIJRE/2024/42345608.

[47] Ogunnaike, M. G., Oyawole, F. P., Afolabi, O. I. and Olabode, J. O. (2021) "Determinants of smallholder farmers' adaptation strategy to climate change in Nigeria", *Kampala International University (KIU) Journal of Social Sciences*, Vol. 7, No. 2, pp 243-251. ISSN 2413-9580.

[48] Onoja, A. O. (2014) "Effects of climate on arable crop farmers' productivity, food security, and adaptation strategies in Nigeria", Ph.D. Thesis. [Online]. Available: https://oer.unn.edu.ng. [Accessed: Nov. 14, 2022].

[49] Onoja, A. O., Achike, A. I. and Enete, A. A. (2018) "Climate change and sustainable green growth in Nigeria: Challenges and opportunities", *Nigerian Agricultural Policy Research Journal*, Vol. 4, No. 1, pp. 1-12. ISSN 2545-5745. DOI 10.22004/ag.econ.314124.

[50] Osuafor, O. O., Ude, K. D. and Ositanwosu, C. O. (2021) "Effect of land degradation on maize yield in Obudu Local Government Area of Cross River State, Nigeria", *Nigeria Agricultural Journal*, Vol. 52, No. 2, pp. 51-60. ISSN 0300-368X.

[51] Otitoju, M. A. (2013) "The effects of climate change adaptation strategies on food crop production efficiency in Southwestern Nigeria", Ph.D. Thesis. DOI 10.22004/ag.econ.187217.

[52] Ozor, N. and Nnaji, C. (2011) "The role of extension in agricultural adaptation to climate change in Enugu State, Nigeria", *Journal of Agricultural Extension and Rural Development*, Vol. 3, No. 3, pp. 42-50. ISSN 2141-2154.

[53] Pringle, P. and Thomas, A. (2019) "*Climate adaptation and theory of change: Making it work for you*", A practical guide for Small Island Developing States (SIDS). [Online]. Available: https://climateanalytics.org/publications/climate-adaptation-and-theory-of-change-making-it-work-for-you [Accessed: March. 2, 2023].

[54] Purwanti, T. S., Syafrial, S., Huang, W. C. and Saeri, M. (2022) "What drives climate change adaptation practices in smallholder farmers? Evidence from potato farmers in Indonesia", *Atmosphere*, Vol. 13, No. 1, p. 113. E-ISSN 2073-4433. DOI 10.3390/atmos13010113.

[55] Rahut, D. B., Aryal, J. P., Manchanda, N. and Sonobe, T. (2022) "Expectations for household food security in the coming decades: A global scenario", In: "*Future Foods: Global Trends, Opportunities, and Sustainability Challenges*", pp. 107-131. ISBN 978-0-323-91001-9. DOI 10.1016/B978-0-323-91001-9.00002-5.

[56] Ukhurebor, K. E. and Uzuazor, I. S. (2020) "Temperature and rainfall variability studies within South-South Region of Nigeria", *Assumption University-eJournal of Interdisciplinary Research*, Vol. 5, No. 2, pp. 1-19. ISSN 2408-1906.

[57] United Nations Development Group. UNDG (2017) "*The theory of change. United Nations Development Assistance Framework (UNDAF) companion guidance*" [Online]. Available: https://unsdg.un.org/sites/default/files/UNDG-UNDAF-Companion-Pieces-7-Theory-of-Change.pdf. [Accessed: Nov. 14, 2022].

[58] United Nations Development Programme. UNDP (2020) "*United Nations Development Programme: Annual report*", New York. [Online]. Available: https://annualreport.undp.org/2020/ [Accessed: Nov. 14, 2022].

[59] World Bank (2016) "*Climate change is a threat – and an opportunity – for the private sector*" An opinion Op-Ed by Tsitsiragos, D. [Online]. Available: https://www.worldbank.org/en/news/opinion/2016/01/13/climate-change-is-a-threat---and-an-opportunity---for-the-private-sector [Accessed: Nov. 17, 2022].

[60] World Bank (2020) "I*mplementation completion and results report: FADAMA III additional financing*", Washington, DC, World Bank. [Online]. Available: https://documents1.worldbank.org/curated/en/540261604338534589/text/Nigeria-Third-National-Fadama-Development-Project.txt[Accessed: Nov. 17, 2022].