Climate Change Impacts And Adaptation Barriers Among Smallholder Cassava Farmer

Ayansina AYANLADE (✉ aayanlade@oauife.edu.ng)

Obafemi Awolowo University

Isaac Ayo OLUWATIMILEHIN

Obafemi Awolowo University

Research Article

Keywords: climate change, Cassava, crop yield, adaptation

Posted Date: December 17th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-1161641/v1>

License: This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Abstract

Climate variability/change has varied impacts on crop yields in many Sub-Saharan African countries. Enhancing the adaptive capacity of rural farmers is a major challenge as climate change becomes threatened to agricultural activities in the region. In this study, the impacts of climate change on cassava crops were examined, and farmers' perceptions of climate, change and their experienced adaptation methods were assessed. Historical climate data and social datasets were used; the adaptation option and barriers to the use of adaptation methods were obtained through questionnaires, semistructured interviews and focus group discussions. Correlation statistics and multiple regressions were utilized to show the impacts of climate on the yield of cassava. The results showed a high variation in climatic variables together with an obvious anomaly index with severity. Minimum and maximum temperatures correlated strongly and positively with the yield of cassava, with 0.86, 0.82 and 0.87, respectively, which were significant at $p > 0.05$. The results of multiple regression showed that climate parameters accounted for 75% of the changes in yield. The results also showed a very strong relationship between crops and rainfall in the early growing season at the $p < 0.05$ level of significance. The majority of the farmers perceived that lack of capital and financial, physical and human capital accounted for 70% of barriers to the implementation of climate change adaptation methods. The key findings here are that the cropping system has been impacted by climate change and that the adaptive capacity of rural farmers in the study area is generally low. The study concludes that although climate change is obvious, there is generally a need to enhance the adaptation options available to farmers in the region.

1. Introduction

Rain-fed farming contributes nearly 90% of Sub-Saharan Africa's (SSA) staple food, provides 60% of the world's food and feed, and forms the major activity of livelihood for approximately 70% of the total population in SSA [1]. Agriculture employs approximately 80% of the labour force in Sub-Saharan Africa, and agriculture has been established by studies to account for approximately 25% of the GDP [2, 3]. However, agriculture in Nigeria, like other parts of SSA, is limited by climate change, as the current climate conditions are not near the desired conditions for farming [4, 5], especially where rainfall is the main source of water for crop production, thereby leading to food shortages. This is because nearly 70% of the population depends on agriculture for income generation [6, 7]. Climate change has been reported to make farmlands vulnerable to bush fires, pests and pathogens and reduce the yield and returns expected by farmers, which will likely discourage many from farming. Going by the growth rate of Nigeria's population and projected to be the third largest country in the world in 2050 [8], there will be an increase in the demand for food for these common food crops (maize, rice and cassava). There is therefore the need to provide explanations and a way forward in coping with the effect of climate change [9, 10]. According to the Intergovernmental Panel on Climate Change [11], climate change is defined as a change in the state of the climate that can be identified by changes in the mean or variability. There are many factors that can affect the yield of crops, including soil type and moisture, crop resistance, rainfall and temperature. Among these factors, temperature and rainfall have been shown to be principal factors that

influence crop production [4, 12, 13]. Additionally, rainfall at the onset and at the closure months of the growing season has been found to be important at the optimum temperature. Studies reveal that climate change generally occurs in rainfall and temperature, as climate determines water availability for the growth and production of crops, which directly affects the yield of crops. Rainfall is important for the stability and quality of yield and can also be a threat to the yield, especially for cassava, as reduced or erratic rainfall during the germination growth stage and the development of tubers can result in decreased yield, just as temperature can encourage the growth of weeds and pest proliferation, thus leading to a reduction in yield[14].

In Nigeria, the production of cassava was originally for food, as it is a source of different indigenous diets, such as *gari*, *eba*, *fufu*, and *amala* [15–18]. Today, cassava has been commercialized following the advent of cassava usage in the production and processing of animal feed, raw material for starch, and ethanol for industrial uses, among others, leading to the exportation of approximately two-thirds of cassava produce not only in Nigeria but also in many countries in SSA [19–23]. Since it is a crop that grows even on poorly drained soil and has less demand for fertile soil and rainfall compared to other crops[24], it is widely grown for different purposes almost everywhere in Nigeria to meet local food demand and with many into commercial production for export. The production of cassava is concentrated in the hands of numerous smallholder farmers in the central and southern regions of Nigeria producing different varieties of cassava [25, 26]. The cropping of cassava has transitioned from traditional production systems to the use of high-yielding varieties and mechanized production and processing. Cassava is a crop of tropical lowlands, and it is restricted to regions that lie within latitudes 30° north and south of the equator with a higher concentration near the equator [27]. It thrives under humid-warm climatic conditions with temperatures ranging between 25°-29°C and precipitation of approximately 1000-15000 mm, which ideally should be evenly distributed throughout the growing season. However, cassava has an enormous ability to adapt to different climatic conditions, as it can survive high temperatures of approximately 37°C and low temperatures of approximately 17°C [28].

The demand for cassava and its products locally and internationally has necessitated an increase in the growth of the crop even in many regions, making it one of the most cultivated crops in SSA countries across different ecological zones[29–31]. Cassava production has been greatly impacted by changing climatic conditions in the country amidst other challenges of cultivation, with no substantial establishment of how it has been impacted by climate well documented in the literature. Hence, this study examines the impact of climate change on cassava crops in a state in Nigeria. Farmers' perceptions of climate, experiences, and adaptive capacity were assessed with the aid of a well-structured questionnaire, semistructured interview and focus group discussion. Climatic data, crop yield data and social data from the questionnaire were analysed using both descriptive and inferential statistics. This study involves the perception of the climate and adaptation capacity of farmers.

2. Methodology

2.1 Study sites

The study sites were among rural farmers in rural communities (Table 1) in freshwater ecological zones situated in Ogun state, Nigeria. The state (Figure 1) is a home of some agricultural produce, with a total land area of approximately 17,000 square kilometres located between latitudes 6°12'0"N and 7°47'60"N and longitudes 3°0'0"E and 5°0'0" east of the Greenwich Meridian [32]. The area is typical of a tropical climate consisting of two different seasons of wet and dry conditions. The wet season is relatively associated with the dominance of the moist maritime southerly monsoon from the Atlantic Ocean, while the dry season is predicted by the continental northeast trade wind from the Sahara Desert. The average temperature value varies according to the months and can be 25.70°C in July and 30.20°C in February. The selected state is ranked among the top agrarian states in Nigeria with similar agricultural practices and methods of cassava crop production.

The major occupation of the people of Ogun state is agriculture, which has employed many people, especially those in rural regions. The state is also known to have many educational institutions that employ many. Several other identifiable modern economic activities exist in Ogun state, and these include insurance, motor companies, petrol stations, light and heavy industries, which also employed a good number of the populace [33].

Table 1
Sampling and sampling locations

State	Settlements	Latitude (°N)	Longitude (°E)	Samples Percent
Ogun	Onibode	7.1420	3.4372	30.5
	Kobape	7.0986	3.3925	30.6
	Odeda	7.2328	3.5281	28.8
	Ota	6.7077	3.2560	10.1
	Total			100
Source: Fieldworks (2019, 2021)				

2.2 Sources of Data and Analyses

Climatic datasets, rainfall, minimum and maximum temperature, were sourced from the archive of the Nigerian Meteorological Agency (NiMet). Oshodi and NiMet used the British Standard Ranguage and Dine's tilting siphon rainfall recorder for rainfall and thermometer. To address the rainfall variability in this zone, we considered the number of rain days, various growing seasons and total rainfall (mm) for each year. In this study, a year is divided into two growing seasons. These seasons are (1) the early growing season from April to June) and (2) the late growing season from July to October. Crop yield data were sourced from the Ogun Agricultural Development Programme (OGADEP), which was derived by dividing the total cassava output by the area of farmland. On the other hand, social data were sourced primarily

from farmers with the aid of a well-structured questionnaire, the Semistructured Interview and Focus Group Discussion (FGD), which were purposively administered to farmers to assess the practice of selected adaptation options as well as barriers. The targeted population for the study was farmers who were 30 years and above. This limit is to obtain data only from experienced farmers who have witnessed different farming seasons. Sampling and sampling locations are presented in Table 1 and Figure 1. Three FGDs with 6 semistructured interviews (SSIs) were conducted to assess the farmers' perceptions of climate and experience. Content analysis was performed to assess the cropping experiences of farmers. The historical profile of the settlement (study area) was collected from the high chief of the settlement, while tent to tent participatory oral interviews were conducted for each farmer in the settlement. The results of the FGD and SSI were analysed using content analysis, while the data from the questionnaire were analysed using descriptive statistics involving frequencies and percentage error graphs to present the adaptive capacity of farmers and barriers to adaptation.

A line graph was plotted using SigmaPlot 10.0 to show changes in climate parameters, while the standardized anomaly index (SAI) was used to assess the annual variation from the mean. Sunburst diagrams and linear dendrograms were used to illustrate social data. The SAI has become the most popular precipitation and temperature index based on hypothetical development and usefulness for analysis [34, 35]. It presents the number of standard deviations from which a climatic record is above or below the climatological average for a station of a particular location. This study employs the use of annual data to calculate the anomaly index as given by the formula in equation 1.

$$g(x) = \frac{x^{\alpha-1} e^{-\frac{x}{\beta}}}{\beta^{\alpha} \Gamma(\alpha)} x, \alpha, \beta > 0 \dots\dots\dots 1$$

where $\Gamma(\alpha)$ is the gamma function, and the two parameters α and β are the scale and shape parameters of the space under consideration, respectively. The calculation of the parameters was obtained for each location on the annual scale. To estimate the parameters, a probability weighted moment was employed using the classification of the anomaly index shown in Table 2. Pearson correlation was used to assess the relationship between crop yield and climate variability. The relationship is as expressed in the equation below:

$$r = \frac{N \sum xy - (\sum x) (\sum y)}{\sqrt{[\sum x^2 - (\sum x)^2] [N \sum y^2 - (\sum y)^2]}} \dots\dots\dots 2$$

where N is the number of pairs of scores, $\sum xy$ is the sum of the products of paired scores, $\sum x$ is the sum of scores, $\sum y$ is the sum of y scores, $\sum x^2$ is the sum of squared x scores, $\sum y^2$ is the sum of squared y scores, x is the crop yield and y is the climate data. Multiple regression was performed to find the combined impact of climate on each of the crops. With the use of climatic (temperature and rainfall) data, the impacts of climate on crop yield were established with the use of multiple regression. The formula for regression is as shown equation 3:

$$b_1 = \frac{(\sum x_2^2)(\sum x_1 y) - (\sum x_1 x_2)(\sum x_2 y)}{(\sum x_1^2)(\sum x_2^2) - (\sum x_1 x_2)^2} \dots\dots\dots 3$$

$$y = a + bX \dots\dots\dots 4$$

where Y= dependent variable, X = independent variable and b= the slope of the line and a = y-intercept.

Table 2
Anomaly categorization

Anomaly class	Categorization
2.0+	Extremely Wet
1.5 - 1.99	Very wet
1.0 - 1.49	Moderately wet
-0.99 – 0.99	Near normal
-1.0 – -1.49	Moderately dry
-1.5 – -1.99	Severely dry
-2 and less	Extremely dry

3. Results & Discussion

3.1. Climate parameters and anomalies

The results revealed high variations in rainfall and temperature both annually and monthly during the study period (Figures 2 and 3). There is high variation in climatic parameters, as shown in Figure 1, which can be linked to global climate change. Significant annual variations in rainfall were observed for each year in relation to annual total rainfall, corroborating the findings that there is variability in several rainfall events recorded at several stations in Nigeria [36]. Climate variability, as documented in a part of Nigeria, among several other places globally, can cause negative departures from the normal climate. Rainfall is associated with SST, as equatorial Indian Ocean SSTs strongly influence rainfall variability in Nigeria in conjunction with the role of the ITD, as the equatorial displacement of the Atlantic subtropical high suppresses the northward summer migration of the ITD, thereby resulting in rainfall variability [37].

The standardized anomaly index (SAI) of annual rainfall and temperature is shown in Figure 3. Categorization around zero is an indication of normal precipitation or temperature, while those markedly above or below zero indicate relatively wet or dry conditions (Figure 3). The maximum temperature was above normal in the first and second decades, moderate in the third decades and has increasingly furthered below normal since the fourth decades. The minimum temperature was generally above normal in the first to the middle of the second decade, moderate to the middle of the third decade and tended

farther below normal. Meanwhile, the rainfall was generally far above normal from the early years covering the study period and about normal to the middle of the second decade after which it went far below and above normal in consecutive years, moderate till the middle of the third decade which went far below normal in 2005 and with adjustment about normal until it was far above normal in 2012 and falls below normal in the consecutive years.

3.2. Changes in yield as evidence effects of climate on cassava

The results of the bivariate correlation analysis between the annual minimum temperature and crop yields during the growing season are shown in Table 3. There is a strong and positive correlation between the yield of cassava and rainfall, cassava and minimum temperature, cassava and maximum temperature. However, significant relationships were recorded for the minimum and maximum temperatures and the yield of cassava. The results of the yield of cassava, rainfall, minimum and maximum temperatures when combined showed 0.75, i.e., accounting for over 75% of changes in crop yield, while the remaining 25% can be explained by other variables, such as edaphic and cassava resistance factors (Table 3). Reduction and erratic rainfall both negatively affect the yield of crops, and the relationship between climate and crop production in Nigeria has been reported to vary depending on the type of crop, seasonal properties and life cycle of the crop under consideration [38–40]. As shown by the results in Table 3, rainfall had a strong relationship with crop yield during both the early and late growing seasons, with $R > 70\%$. The results further showed a very strong relationship between crops and rainfall in both early and late growing seasons (Table 3). Previous studies have reported that rainfall can be maximized for crop production only when temperature and relative humidity are at high levels. While rainfall variability is capable of influencing maize yield, it was reported that temperature is capable of contributing approximately 50% to changes in yield; relative humidity can bring about an increase in yield when it is usually high throughout the growing season. The relationship is, however, influenced by the level of inputs [41, 42].

Table 3
Correlation between climate and crop yield

Cassava yield	Rainfall	Min temperature	Maximum temperature
Annual	0.84	0.82*	0.87*
Early growing season	0.79*	0.42	0.37
Late growing season	0.75*	0.32	0.57
* Significant at $p < 0.05$ *			

Despite changes in climate conditions, the study found an increase in cassava production, as illustrated in Figure 4. Yet, earlier study have shown that long dry spells combined with high temperatures can have a severe influence on yield, since the effects of rainfall and temperature on tuber crops are clear, particularly for cassava, which can reach 95% probability levels[43, 44]. Because rainfall volume and

frequency during the time immediately following planting affect yield, an increase in land committed to cassava production may not result in a comparable increase in yield. Although, cassava is less sensitive to rainfall at the start and end of the growing season, several factors can account for a reduction in cassava yield, as both reduced and erratic rainfall can affect yield, but it also depends on the level of inputs, such as fertilizer and the planting of resistant species [14]. With the introduction of climate-smart cassava varieties and the liberalization of the seed value chain, which enhances the availability of improved seeds to farmers, it is possible to boost yield even with a reduction in land area [44–46].

3.3. Practice of adaptation and adaptation options based on gender

Adaptation practices have been reported to be dependent on the age of farmers, farm size and level of production. The study observed that despite the statistical evidence of changes in climate parameters, yield increased. The practice of adaptation option is shown in Figure 5. From the figure, mixed farming planting of different species or varieties, agricultural intensification, bush fallowing, changes in seasonal timing of sowing and harvest and the use of credit facilities actually helped enhance the yield of cassava over the study period. There has been an expansion on adaptation to current and projected impacts of climate change to include barriers to adaptation, and these have raised questions around social, financial, cultural, environmental and ecological conditions and changes that can hamper the ability of a farmer to adapt to climate change [47].

The study further examined the causes for the low level of adaptation, and the results of the broad obstacles to adaptation method adoption in the study area. It is obvious from Figure 6 that 41.1% of people are unable to practice some adaptation methods since they face a low risk of climate change. It is noticeable that low probability of climate change accounted for 42.3%, low severity of climate change accounted for 43.5%, low benefits from adaptation measures accounted for 50.6%, low ability to adapt accounted for 63.7%, lack of financial capital accounted for 70.2%, lack of physical capital accounted for 73.8%, lack of human capital accounted for 82.7%, lack of natural capital accounted for 83.3%, lack of social capital accounted for 83.3%, while lack of financial capital accounted for 70.2%. Lack of external support or isolation, particularly from family members, accounted for 23.2%, habits, customs, and local preferences accounted for 34.5%, cultural, religious, and social norms accounted for 21.4%, other adaptation options with similar purposes accounted for 23.8%, incompatible trade-offs of adaptation options accounted for 26.2%, and fear of potential risk or adverse effects accounted for 10.7%. (Figure 6).

In particular, the perceptions of climate change impacts, adaptation and barriers to adaptation methods vary by gender (Tables 4 and 5). Nearly 65% and 35% of farmers in the study areas are male and female, respectively, in terms of population. Adaptation practices by rural farmers based on gender differed much more, but both perceived that the temperature of the hottest month was believed to be warmer by a higher proportion of the respondents. Many think that extreme floods are more frequent, while extreme drought and the durations of the rainy and dry seasons have remained the same. The farmers' perception of lack of capital is probably responsible for low adaptation practices in the study area. Generally, their adaptive

capacity is low, although the most practised adaptations were irrigation, use of loans and credit facilities, agricultural intensification, and agroforestry, among others. Additionally, climate change, societal change and ecological change have led to farmers abandoning some landrace crops, such as palm produce, cocoyam and water yam, which are considered to be less productive, and they have adopted new crops, such as water melon, cucumber and pepper, based on market demand. The majority of the farmers are not practicing specific adaptation methods, and the study investigated barrier adaptation and found that a lack of financial, natural, social and physical capital is generally a barrier to adaptation, although some deliberately have not taken any measure or have chosen not to practice adaptation (Table 5). Earlier studies have reported climate change adaptation differences by gender. The majority of them stated that farmers' adaptation strategies are said to vary according on their gender, age, farm size, and farming experiences. In the present study however, barriers to adaptation have been added to the discussion of adaptation to current and future impacts of climate change, raising questions about social, economic, cultural, environmental, and ecological factors and changes that can impede a farmer's ability to adjust to climate change [47, 48]. Generally, most farmers in Africa have already perceived an increased temperature coupled with insufficient precipitation for production. However, studies have indicated that approximately one-third of farmers in Africa have not changed their farming techniques despite their perception of climate change, which is high for reasons unknown[31, 43]. Climate change, market demand and societal change have led to different farmers abandoning some landrace crops. Different adaptation options were assessed, and the results varied spatially, as the level of adaptation was highest in Ondo, followed by Kwara and lowest in Ogun state. The most practised adaptation options are agroforestry, changes in harvest time, securing loan and credit facilities, agricultural intensification and irrigation. However, the results also showed that the adaptation levels of the farmers across the three ecological zones were generally low. Additionally, the results of barriers to adaptation showed that the barriers to adaptation are primarily on capital in different forms, such as human capital, financial capital, natural capital and social capital.

Gender has been identified to play a critical role in the use and practices of mitigation and adaptive measures of climate change in many societies due to indigenous knowledge and leadership in sustainable resource management, leading sustainable practices at the household and community levels. Poor women's participation at the political level has resulted in greater responsiveness to citizens' needs and has been increasing cooperation across party and ethnic lines and delivering more sustainable peace. The impact of climate change will be disproportionately harsh for the poorest countries and the most vulnerable people and groups, particularly women [49]. It is therefore important to recognize the adaptation capacities of both males and females to understand gender-based adaptation differences since climate change affects men and women differently. Women who receive less education tend to be poorer, and in the decision-making process, they are usually excluded at both the political and household levels. Notably, the present study assesses gender differences in adaptation and barriers to adaptation, as presented in Tables 4 and 5.

Table 4
Adaptation practices by rural farmers based on gender

Adaptation Options		
	Male	Female
Agricultural Diversification	61.1	38.9
Changes in crop cultivation	59.3	40.7
Crop Rotation	60	40
Mixed farming	57.9	42.1
Changes in Size of farmland	61.1	38.9
Different crop composition	57.9	42.1
Agricultural Intensification	60.7	39.3
Bush fallowing	57.1	42.9
Changes in daily working time	58	42
Agroforestry	70	30
Changes in seasonal timing of sowing	60	40
Changes in harvest time	73.3	26.7
Use of irrigation	56.9	43.1
Fertilizer application	58.5	41.5
Pesticide application	58.8	41.2
Loan & credit facilities	70.4	29.6
Changes in income	61.2	38.8
Changes in food storage	58.7	41.3
Changes in quantity of food consumed	87.5	12.5
Changes in residence	71.4	28.6

Table 5
Barriers to adaptation practices by rural farmers based on gender

Barriers Option	Male	Female
Low climate change risk	78.9	21.1
Low probability of climate change impact	80	20
Low severity of climate change	63.2	36.8
Low benefits from adapting measures	55.9	44.1
Low ability to adapt	55.3	44.7
Lack of financial capital	59.5	40.5
Lack of physical capital	56.8	43.2
Lack of human capital	59.1	40.9
Lack of natural capital	61.2	38.8
Lack of social capital	60	40
Lack of time	66.7	33.3
Lack of external support	64.3	35.7
Distance or isolation	60	40
Habit/custom/preference	64.3	35.7
Cultural/religion/social norms	55.6	44.4
Legal framework or regulation	55.6	44.4
Other adaptation with similar purpose preferred	37.5	62.5
Incompatibility of tradeoffs	50	50
Fear of potential risks or adverse effects	60	40

What is obvious from the results of this study is that the relationship between climate change and crop production in Nigeria varies depending on the type of crop, seasonal properties and life cycle of the crop[50, 51]. Generally, the climate change effect was found to be pronounced on the output of crops, as an increased occurrence of dryness in terms of elongated spell length is capable of reducing yield [52–54]. Climate variability has implications that are significant for global and regional food production, for which the extent of the impacts remains uncertain to an extent, as the impacts of climate variability on some common classes of food crops, including tubers, grains, legumes and vegetables, vary as the mean temperature and moisture requirements vary with tuber crop production.

4. Conclusions

In this study, the observed impact of climate change on cassava crops was examined, and rural farmers' perceptions of climate, experiences, and adaptive capacity were assessed with the aid of a well-structured questionnaire, semistructured interview and FGD. It was observed that the rainfall and temperature were markedly with high variations, which also correlated strongly and positively with the yield of cassava. However, the study observed a general increase in the yield of cassava throughout the study, which is occasioned by fair practice of adaptation measures, especially the introduction of improved species of cassava that takes less time to maturity when compared with the local species grown in the past, although adaptation practices are generally low among the farmers. The study recommends enhancement of adaptation options available to farmers in the region for better yield to unlock new business opportunities for the country through cassava processing.

A significant number of farmers interviewed during the FGD of this study already believed that temperature has increased and rainfall has declined, with those with a high experience of farming likely to notice climate change. However, there are differences in the ability of farmers to adapt, as their adaptive capacities vary significantly. Generally, climate change is a reality, and its effect has negative impacts in Africa, leading to food shortages [55]. However, climate change awareness and adaptive education through extension workers have helped farmers cope with the menace of climate change. As warming poses a high risk to agriculture, irrigation, multiple cropping and integration of livestock will benefit most African farmers. Better access to markets, extension and credit services, technology and farm assets (land, labour and capital) are also effective adaptation measures and have been ongoing in Africa [56]. Given the observations in this study, the following recommendations are made with regard to the impact of climate on crops in selected ecological zones in Nigeria. Although the government, international bodies and local organizations are funding adaptations through loan and credit facilities to farmers, this is still inadequate. Therefore, there should be better participation to curb food insecurity challenges in Nigeria in general and specifically in the study area, including Ondo, Ogun and Kwara states. Farmers should engage in planting crops that require more moisture in the late growing season, which, as revealed by the study, has more moisture than in the early growing season, while crops that can endure or require higher temperatures should be grown in the early growing season. The study showed that maize is less sensitive to climate, unlike rice and cassava; farmers should engage more in growing maize to enhance their yield.

The challenge of improving the yield of staple crops such as maize, rice and cassava in Nigeria is generally heightened by the increasing temperatures and unpredictability of rainfall. Climatic records should therefore be made available to farmers, and predictions and forecasts for farming seasons should be made available to better prepare farmers for uncertainties to come. Early planting portends dry spells for maize and rice. It is therefore recommended that farmers who will engage in early planting of these crops should make use of irrigation options for better yields, as dryness and hot spells can follow the first, second and third events of the year, which can even influence temperature, thereby exposing crops to severe conditions. The loans and credit facilities through the government and her agents do not get

directly to local farmers. As claimed by their farmers, it is only the rich farmers that can assess government farm inputs. There is a need for affordable and available improved seedlings and a variety of crops that can adapt to diverse climatic conditions. Importantly, the government, through her agencies such as the extension workers of the Agricultural Development Programme and corporate organizations, should engage more in sensitizing farmers about climate change and the need to adopt coping strategies for enhanced yield. Farmers generally depend on rain-fed agriculture; therefore, short-term fluctuations in weather patterns have significant impacts on their cropping activities. There is a need for adjustment to short-term anomalies within a reasonable economic and technological limit. To assist farmers in better coping with climate variability and potential long-term climate changes, government policies must address and increase farmers' prospects for better adaptive responses while enhancing the availability and affordability of inputs such as fertilizer, seedlings, pesticides, and herbicides.

Declarations

Availability of data and materials

The underlying data can be made available upon request to the corresponding author.

Ethics approval and consent to participate

This study conforms with the ethics principles of Obafemi Awolowo University. Ethical approval for this study was obtained with standard ethics as the participants were not vulnerable in anyway, data was processed in anonymous procedure, and survey participants had the possibility to skip questions.

Consent for publication

Not applicable, because there is no data contained within our manuscript from which individual patients or participants may be identified.

Acknowledgement

The authors wish to express their gratitude to the management and staff of the Nigerian Meteorological Agency, Oshodi, Lagos for supplying the rainfall and temperature data and Ogun State Agricultural Development Programme (OGADEP) for supplying crop yield data for this work. A.A. also acknowledges support from a small research grant by the International Development Research Centre, Ottawa, Canada, and with financial support from the Government of Canada, provided through Global Affairs Canada (GAC), under the framework of the Mathematical Sciences for Climate Change Resilience (MS4CR) program administered by AIMS. And, support from the Queen Elizabeth Scholars project on ecological economics, commons governance, and climate justice, with funding from the Canadian Queen Elizabeth II Diamond Jubilee Scholarships Advanced Scholars Program (QES-AS). This work was supported and partly funded by the Tertiary Education Trust Fund, TETFund NRF 2020 Nigeria (GrantAward - TETF/DR&D-CE/NRF2020/CC/17/VOL.1).

Author Contributions

AA and I.A.O. developed the conception and every aspect of this study; AA played the leading role in the supervision of the research project, through which the paper was developed, While I.A.O. analysed the data. All authors contributed to the paper writing and approved the final manuscript.

Correspondence and requests for materials should be addressed to A.A.

Competing Interests: The authors declare that they have no competing interests.

References

1. Bischiniotis, K., et al., *The influence of antecedent conditions on flood risk in sub-Saharan Africa*. Natural Hazards and Earth System Sciences, 2018. **18**(1): p. 271–285.
2. Griffin, T.E., *Lake Chad*.
3. Amani, A., et al., *Strengthening Flood and Drought Risk Management Tools for the Lake Chad Basin*. Climate Change and Water Resources in Africa: Perspectives and Solutions Towards an Imminent Water Crisis, 2021: p. 387-405.
4. Ayanlade, A., et al., *Rainfall variability and drought characteristics in two agro-climatic zones: An assessment of climate change challenges in Africa*. Science of the Total Environment, 2018. **630**: p. 728–737.
5. Adejuwon, J. *Crop yield response to climate variability in the Sudano-Sahelian ecological zones of Nigeria in southwestern Nigeria*. in *AIACC Report of Workshop for Africa and Indian Ocean Island*. Dakar, Senegal. 2004.
6. Höhn, A., et al., *After the flood and with the people—Late Holocene changes of the woody vegetation in the southwestern Chad Basin, Nigeria*. Quaternary International, 2021. **593**: p. 224–235.
7. Pierre, T.J., et al., *Characteristics, classification and genesis of vertisols under seasonally contrasted climate in the Lake Chad Basin, Central Africa*. Journal of African Earth Sciences, 2019. **150**: p. 176–193.
8. Abubakar, I.R. and U.L. Dano, *Socioeconomic challenges and opportunities of urbanization in Nigeria*, in *Urbanization and its impact on socio-economic growth in developing regions* 2018, IGI Global. p. 219-240.
9. Loum, A. and C. Fogarassy, *The effects of climate change on cereals yield of production and food security in Gambia*. APSTRACT: Applied Studies in Agribusiness and Commerce, 2015. **9**(1033-2016-84322): p. 83.
10. FAO, *Report of the World Food Summit*, in *World Food Summit* 1996: Rome.
11. IPCC, *Climate Change 2007 - Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the IPCC.*, O.F. Parry, Canziani, J.P., Palukitof, P.J., Van der Linden and Hanson eds, Editor 2007, Cambridge University Press: Cambridge.

12. Bang, S., et al. *Fuzzy Logic based Crop Yield Prediction using Temperature and Rainfall parameters predicted through ARMA, SARIMA, and ARMAX models*. in *2019 Twelfth International Conference on Contemporary Computing (IC3)*. 2019. IEEE.
13. Cammarano, D., et al., *Rainfall and temperature impacts on barley (*Hordeum vulgare* L.) yield and malting quality in Scotland*. *Field Crops Research*, 2019. **241**: p. 107559.
14. Oseni, T. and M. Masarirambi, *Effect of climate change on maize (*Zea mays*) production and food security in Swaziland*. *change*, 2011. **2**: p. 3.
15. Woodley, E., *Building Nigeria's Response to Climate Change: Pilot Projects for Community-Based Adaptation in Nigeria*, in *Experiences of Climate Change Adaptation in Africa* 2011, Springer. p. 297–315.
16. Kolawole, P.O., L. Agbetoye, and S.A. Ogunlowo, *Sustaining world food security with improved cassava processing technology: The Nigeria experience*. *Sustainability*, 2010. **2**(12): p. 3681–3694.
17. Eyinla, T., *Evaluation of starches digestibility and glycemic index of commonly consumed staple foods from selected varieties of cassava (*Manihot* sp.) and yam (*Dioscorea* sp.)*, 2019, University of Ibadan.
18. Oluwamukomi, M.O. and O.S. Lawal, *Textural characteristics of Nigerian foods*. *Textural Characteristics of World Foods*, 2020: p. 361–383.
19. Bain, L.E., et al., *Malnutrition in Sub-Saharan Africa: burden, causes and prospects*. *Pan African Medical Journal*, 2013. **15**(1).
20. Yadav, S.S., et al., *Climate change, agriculture and food security*. *Food Security and Climate Change*; Yadav, SS, Redden, RJ, Hatfield, JL, Ebert, AW, Hunter, D., Eds, 2019.
21. Behnassi, M., et al., *Enhancing Resilience for Food and Nutrition Security Within a Changing Climate*, in *Emerging Challenges to Food Production and Security in Asia, Middle East, and Africa* 2021, Springer. p. 1-42.
22. Onyenechere, E., *Climate change and spatial planning concerns in Nigeria: Remedial measures for more effective response*. *Journal of Human Ecology*, 2010. **32**(3): p. 137–148.
23. Murumkar, A., et al., *Trends and spatial patterns of 20th century temperature, rainfall and PET in the semi-arid Logone River basin, Sub-Saharan Africa*. *Journal of Arid Environments*, 2020. **178**: p. 104168.
24. Descheemaeker, K., et al., *Climate change adaptation and mitigation in smallholder crop–livestock systems in sub-Saharan Africa: a call for integrated impact assessments*. *Regional Environmental Change*, 2016. **16**(8): p. 2331–2343.
25. Diakite, A., J. Bayala, and C. Dembele, *End-line study-Capacitating Stakeholders in Using Climate Information for Enhanced Resilience in the Agricultural Sector in West Africa (CaSCI ERA-TA)*. 2020.
26. Ekwezuo, C.S. and C.U. Ezeh, *Regional characterisation of meteorological drought and floods over west Africa*. *Sustainable Water Resources Management*, 2020. **6**(5): p. 1–11.

27. Onyeneke, R.U., et al., *Evidence-Based Policy Development: National Adaptation Strategy and Plan of Action on Climate Change for Nigeria (NASPA-CCN)*. African Handbook of Climate Change Adaptation, 2020: p. 1-18.
28. IITA, *Growing in Nigeria. Commercial Crop Production Guide Series. Information and Communication Support for Agricultural Growth in Nigeria.*, 2012: USAID. p. 1–8.
29. Gebrechorkos, S.H., S. Hülsmann, and C. Bernhofer, *Analysis of climate variability and droughts in East Africa using high-resolution climate data products*. Global and Planetary Change, 2020. **186**: p. 103130.
30. Araro, K., S.A. Legesse, and D.T. Meshesha, *Climate change and variability impacts on rural livelihoods and adaptation strategies in Southern Ethiopia*. Earth Systems and Environment, 2020. **4**(1): p. 15–26.
31. Kogo, B.K., L. Kumar, and R. Koech, *Climate change and variability in Kenya: a review of impacts on agriculture and food security*. Environment, Development and Sustainability, 2021. **23**(1): p. 23–43.
32. Solanke, M., *Intra-Urban work and school trips characteristics in Ogun state, Nigeria*. International Journal of Development and sustainability, 2013. **2**(2).
33. Solanke, M., *Spatial pattern and organisational structure of intra-urban trips in Ogun State, Nigeria*. Ethiopian Journal of Environmental Studies and Management, 2015. **8**(1): p. 13–27.
34. Ghosh, S. and P.P. Mujumdar, *Nonparametric methods for modeling GCM and scenario uncertainty in drought assessment*. Water Resources Research,, 2007. **43**(7).
35. Rivera, J.A. and O.C. Penalba, *Trends and spatial patterns of drought affected area in Southern South America*. Climate,,, 2014. **2**(4): p. 264–278.
36. Adejuwon, J.O., *Food crop production in Nigeria. I. Present effects of climate variability*. Climate Research, 2005. **30**(1): p. 53–60.
37. Bello, W., *Will Capitalism survive Climate Change?* Chain Reaction,, 2008. **104**: p. 44.
38. Oguntunde, P.G., B.J. Abiodun, and G. Lischeid, *Impacts of climate change on hydro-meteorological drought over the Volta Basin, West Africa*. Global and Planetary Change, 2017. **155**: p. 121–132.
39. Enete, I., *Impacts of climate change on agricultural production in Enugu state, Nigeria*. Journal of Earth Science & Climatic Change, 2014. **5**(9).
40. Eregha, P., J. Babatolu, and R. Akinnubi, *Climate change and crop production in Nigeria: An error correction modelling approach*. International Journal of Energy Economics and Policy, 2014. **4**(2): p. 297.
41. Agbossou, E., et al., *Climate variability and implications for maize production in Benin: A stochastic rainfall analysis*. African Crop Science Journal, 2012. **20**(2): p. 493–503.
42. Mawonike, R. and G. Mandonga, *The effect of temperature and relative humidity on rainfall in gokwe region, zimbabwe: a factorial design perspective*. International Journal of Multidisciplinary Academic Research,, 2017. **5**(2): p. 36–46.

43. Amanambu, A.C., et al., *Spatio-temporal variation in rainfall-runoff erosivity due to climate change in the Lower Niger Basin, West Africa*. Catena, 2019. **172**: p. 324–334.
44. Ayanlade, A., et al., *Climate Change Adaptation Options in Farming Communities of Selected Nigerian Ecological Zones*, in *African Handbook of Climate Change Adaptation*, W. Leal Filho, et al., Editors. 2020, Springer International Publishing: Cham. p. 1-16.
45. Umar, U.A., M.B. Muhammed, and A.S. Aliyu, *Maize Production and Yield improvement in Nigeria*. Agricultural Research Council of Nigeria, 2014.
46. Ayanlade, A., *Geospatial Analysis of Rainfall Variability Impacts on Crop Yield in the Guinea Savanna Ecological Zone of Nigeria, (Doctoral dissertation), OAU Ife, Nigeria*, 2015.
47. Biesbroek, G.R., et al., *On the nature of barriers to climate change adaptation*. Regional Environmental Change, 2013. **13**(5): p. 1119–1129.
48. Oluwatimilehin, I.A. and A. Ayanlade, *Agricultural community-based impact assessment and farmers' perception of climate change in selected Ecological Zones in Nigeria*. Agriculture & Food Security, 2021. **10**(1): p. 1–17.
49. UNDP, U.N.D.P.- *Gender and Adaptation*. Policy Brief 2., 2012 21/01/2020]; Available from: https://www.undp.org/content/dam/undp/library/gender/Gender%20and%20Environment/PB2_Africa_Gender-and-Adaptation.pdf.
50. Shanahan, T.M., et al., *Simulating the response of a closed-basin lake to recent climate changes in tropical West Africa (Lake Bosumtwi, Ghana)*. Hydrological Processes: An International Journal, 2007. **21**(13): p. 1678–1691.
51. Odekunle, T., I. Orinmoogunje, and A. Ayanlade, *Application of GIS to assess rainfall variability impacts on crop yield in Guinean Savanna part of Nigeria*. African journal of Biotechnology, 2007. **6**(18).
52. Choudhary, S., et al., *Maize, sorghum, and pearl millet have highly contrasting species strategies to adapt to water stress and climate change-like conditions*. Plant Science, 2020. **295**: p. 110297.
53. Han, F., K.H. Cook, and E.K. Vizzy, *Changes in intense rainfall events and dry periods across Africa in the twenty-first century*. Climate Dynamics, 2019. **53**(5-6): p. 2757–2777.
54. Sniderman, J.K., et al., *Southern Hemisphere subtropical drying as a transient response to warming*. Nature Climate Change, 2019. **9**(3): p. 232–236.
55. Maddison, D., *The perception of and adaptation to climate change in Africa* 2007: The World Bank.
56. Hassan, R.M. and C. Nhemachena, *Determinants of African farmers' strategies for adapting to climate change: Multinomial choice analysis*. African Journal of Agricultural and Resource Economics, 2008. **2**(311-2016-5521): p. 83–104.

Figures

Figure 1

Map of the study area showing weather station (blue) and sample village (red) points

Figure 2

Pattern of climate in the study area

Figure 3

Standardized Anomaly Index of climate parameters

Figure 4

Changes in yield of cassava

Figure 5

Practices adaptation methods for rural farmers

Figure 6

Barriers to practicing adaptation in percentages ranked by farmers