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Climate change impacts on staple crops: Assessment of smallholder farmers' adaptation methods and barriers

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A R T I C L E I N F O

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A B S T R A C T

Crops in Sub-Saharan African countries are generally more vulnerable to climate change with considerable impacts on yields. In this study, the impacts of climate change on selected root crops, cereals and vegetables were examined with the practice of adaptation as well as barriers hindering the adoption of selected adaptation options in selected farming communities in Ogun state, Nigeria. The climate dataset ranging from 1982 to 2020 and crop yield data ranging from 1996 to 2020 were used in this study. The social data was collected through a structured questionnaire administered among a total of 120 rural farmers purposively selected for the study. The data collected were analysed and presented using descriptive statistics, bivariate correlations and regression statistics. The results showed a high variation in climatic variables together with an obvious anomaly index with severity. The correlation results indicate a strong relationship between rainfall minimum/maximum temperatures and most crops, with $R > 0.60$, at $p > 0.05$. The results of multiple regression showed $R^2 \leq 0.64$ values for all crops at $p < 0.05$. This result implies that climate parameters accounted for significant percentage of the changes in yields. The results also showed low practice of adaptation among rural farmers and the major barrier hindering the practice of adaptation is lack of capital, including financial, physical, and human capital, which was responsible for 70% of the hurdles to climate change adaptation measures implementation. 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 smallholder farmers in the region.

1. Introduction

Climate change remains the major challenge facing agriculture in the African continent and it has been projected that climate change may lead to about 80% change in the yield of crops in the region (Knox et al.,2012;Sultan et al., 2013; Trisos et al., 2022). Climate extreme events such as erratic rainfall, delayed onset and offset of seasons as well as heat waves, have been reported to make farming more challenging (Collier et al., 2008, Clay and King, 2019, Ayanlade et al., 2022b). There are global long term temperature and rainfall changes, although the impacts of these changes are mostly spatio-temporal specific, the condition in Sub-Saharan African (SSA) countries is worse. This is simply because rain-fed agriculture is widely practised and it contributes nearly 90% of SSA's staple

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food and forms the major activity of livelihood for approximately 70% of the total population in SSA (Bischiniotis et al., 2018). Agriculture is an important means of livelihood in SSA and contributes about 25% of the total GDP. The agricultural sector also employs approximately 70% of the labour force in Sub-Saharan Africa (Griffin, Amani et al., 2021, Trisos et al., 2022). However, climate change constitutes a major risk to this important sector. The recent climatic conditions in SSA have been reported to make farmlands more vulnerable to bushfires, pests and pathogens. Also, it has been associated with reduced yield resulting from delays in the onset of seasons, erratic rainfall and heat waves. These are likely going to discourage many from farming in SSA. Climate change has been reported in the literature to have affected water availability and variability directly impacts the production of staple crops, which are vital for ensuring food availability and livelihoods, particularly in rural areas(Ayanlade et al., 2022a, Ajjur and Al-Ghamdi, 2021, Coulibaly et al., 2018). In Africa, Rice, maize, cassava, and potatoes are stapled crops that form the backbone of many food production systems, feeding millions of people.

Studies have reported the implications of climate factors on crop yield. Among these factors, temperature and rainfall have been found to be principal factors that influence crop production (Bang et al., 2019, Cammarano et al., 2019, Ayanlade et al., 2018b). Additionally, rainfall at the onset and the end 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, as reduced or erratic rainfall during the germination growth stage and the development of tubers can result in decreased yield, just as the temperature can encourage the growth of weeds and pest proliferation, thus leading to a reduction in yield (Oseni and Masarirambi, 2011).

Understanding how rural farmers adapt to the impacts of climate change on staple crop production is crucial for devising effective policies and interventions to enhance agricultural resilience and food security. Previous studies have explored various adaptation methods employed by farmers, ranging from altering planting dates and crop varieties to implementing irrigation and water management systems. These adaptive measures are aimed at minimizing climate-related risks and optimizing crop yields. Many adaptation methods have been used by rural farmers, yet rural farmers often encounter numerous barriers, which are socio-economic, technological, institutional, or informational in nature (Aryal et al., 2021, Ayanlade et al., 2018a, Barros et al., 2014). For instance, limited access to credit and financial resources may restrict farmers' capacity to adopt new technologies or implement climate-smart agricultural practices. Farmers' decision-making processes might also be hampered by a lack of knowledge and awareness regarding climate change and possible adaptation solutions (Danso-Abbeam et al., 2021, Trisos et al., 2022). As a result, there is a need for thorough study that explores rural farmers' adaptation tactics and the constraints they confront in the context of climate change and staple crop production. By gaining insights into the current adaptation practices and identifying the challenges encountered by farmers, policymakers, agricultural extension services, and other relevant stakeholders can develop targeted interventions and support mechanisms to enhance adaptive capacity at the grassroots level.

This study aims to address this research gap by assessing the impacts of climate change on crops (Cassava, yam, coco-yam, sweet potato, tomato, pepper, okra, maize, rice, and melon) and adaptation methods employed by rural farmers in the face of climate change as well as barriers to their practice of adaptation in Ogun state Nigeria, where the majority of these crops are produced on a large scale favoured by different ecological conditions ranging from mangrove and freshwater in the southern part of the state that borders the Atlantic Ocean to the derived savanna in the northern part of the state. By conducting surveys, and on-site observations, this research seeks to document and analyze the range of adaptation strategies implemented by farmers, their effectiveness in mitigating climate-related risks, and the underlying factors that hinder or facilitate their adoption. For this study, crops were selected and categorized under root crops, cereals and vegetables. Also, the relationships between the selected crops and climate were analysed. The findings of this study will provide valuable insights into the dynamics of adaptation in agricultural systems, informing evidence-based policies and strategies to build resilience and ensure sustainable staple crop production in the face of climate change. The major limitation of this study is the fact that analysis is based on a specific time period, and the dataset might not fully capture long-term trends in crop yields. Longer time-series data would provide a more comprehensive understanding of historical trends and could potentially reveal patterns not observed within the selected time frame.

2. Methodology

2.1. Study sites

This study was conducted among smallholder farmers in communities (Table 1) in freshwater ecological zones situated in Ogun

Table 1
Sampling and sampling locations.

State	Settlements	Latitude (^{0}N)	Longitude (^{0}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).

State, Nigeria. The state (Fig. 1) is an agrarian state and home to different crops that serve as staples in Nigeria. Ogun state has 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 (Solanke, 2013). 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 month and can be 25.70 °C in July and 30.20 °C in February. The state is ranked among the top agrarian states in Nigeria with agricultural practices and methods of crop production similar to what is obtainable in other states (Bamiro et al., 2012, Ayanda et al., 2013, Teeken et al., 2018).

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 noted for its numerous educational institutions, which employ a large number of people. Several other identifiable modern economic activities exist in Ogun state, and these include insurance, motor companies, petrol stations, light and heavy industries (Solanke, 2015). This study employed the use of purposive sampling techniques to select rural settlements with intensive agricultural activities.

2.2. Sources of data and analyses

Climatic datasets consisting of monthly rainfall, minimum and maximum temperatures were sourced from the archive of the Nigerian Meteorological Agency (NiMet), Oshodi. The data were collected by the agency using the British Standard Rainguage 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. Crop yield data of 25 years (1996–2020) was sourced from the Ogun Agricultural Development Programme (OGADEP). The crop data used is only available for this period and was derived by dividing the total crop output (in metric tons per hectare) by the area of farmland. On the other hand, social data was sourced primarily from farmers with the aid of a semi-structured questionnaire which was purposively administered to farmers to assess the practice of selected adaptation options as well as barriers. The targeted population for the study were farmers that have had about 30 years and above farming experience. This limit is to obtain data only from experienced farmers who have witnessed different

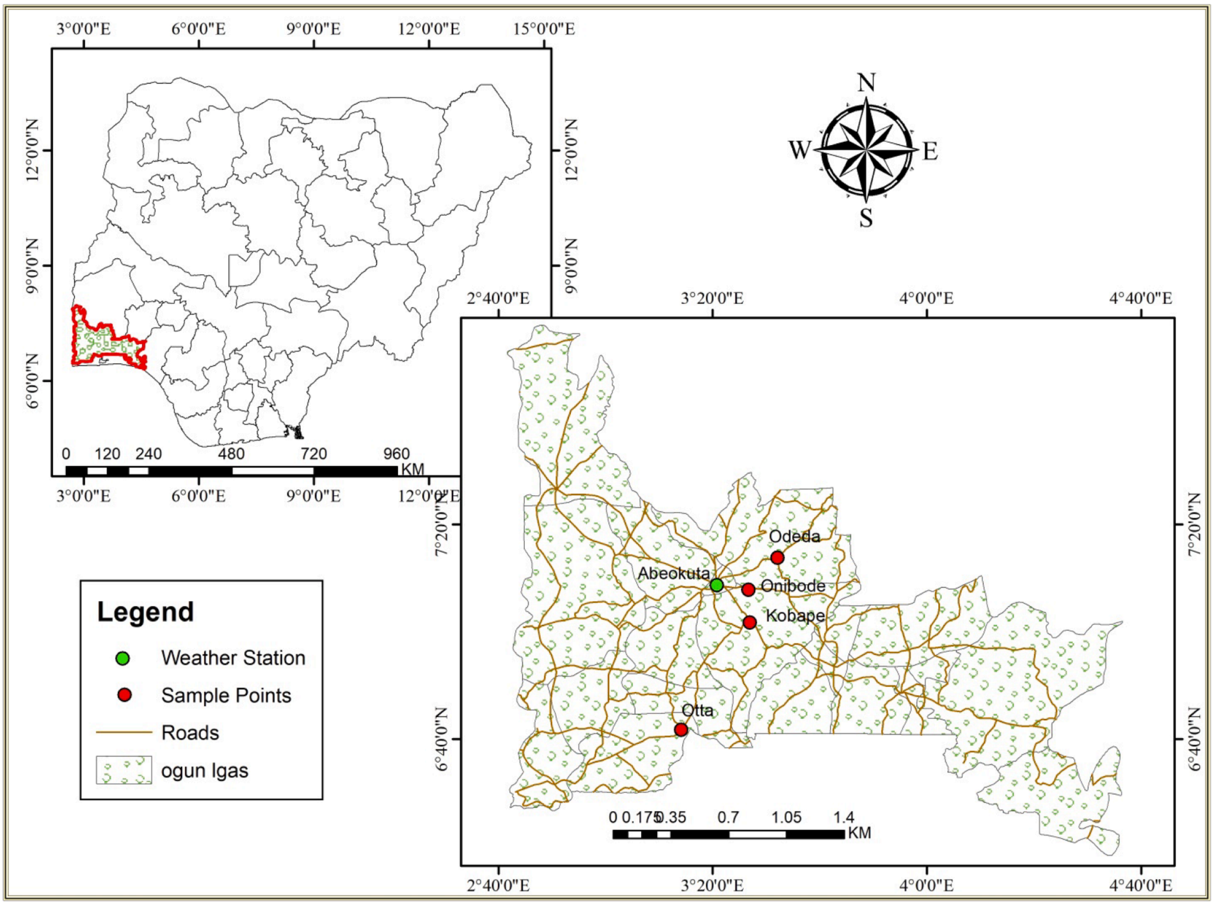

Fig. 1. Map of the study area showing weather station (green) and sample village (red) points.

farming seasons. On this note, 4 farming settlements were selected for this study where 30 copies of a questionnaire were distributed each. In total, 120 copies of the questionnaire were used for this study. Sampling and sampling locations are presented in Table 1 and Fig. 1.

A line and bar charts were plotted using Microsoft Excel Version 2016 from Microsoft Corporation to show changes in climate parameters, while the standardized anomaly index (SAI) was plotted using SigmaPlot 10.0 to analyse the Standard Anomaly Index (SAI) relating to the annual variation from the mean and to illustrate the social data. The SAI 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 Eq. (1).

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

where (α) 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 an annual scale. To estimate the parameters, a probability-weighted moment was employed using the classification of the anomaly index shown in Table 2. Mann Kendall statistics was used to examined the trend in climate and crop parameters with the aid of Paleontological Statistical Software package for education and data analysis (PAST) Version 3.20. Two research hypothesese are usually assumed for the Mann Kendall test (Ho: There is no statistical trend in the time series data and H1: there is a statistical trend in the time series data). Where S is the slope, Z is the MK trend. The critical value of Z at p-value of 0.05 is 1.96. Therefore, a positive value of Z greater than 1.96 indicates an upward trend while a negative value is an indication of downward trend at $p < 0.05$. (Oluwataimilehin and Ayanlade 2021). Pearson correlation and linear regression were done to assess the relationship between crop yield and climate parameters using Statistical Packages for Social Sciences (SPSS) Version 21 from IBM.

3. Results & discussion

3.1. Climate parameters and anomalies

The results shows notable annual fluctuations in temperature and precipitation between 1982 and 2020 (Fig. 2), with high climatic parameters and notable annual variations in precipitation relative to total precipitation. Interesting insights are revealed by trend analysis of climatic data.The R-squared values show how well linear regression models are able to predict data trends. A larger fraction of variance is indicated by a higher R-squared value. With an R^2 value of 0.67, the lowest temperature has the strongest linear relationship with time. A linear trend shows around 67% of the fluctuation in minimum temperature, demonstrating a dependable and predictable pattern. Time and maximum temperature significantly correlate, and maximum temperature has a strong linear association with an R^2 value of 0.56. The linear trend may explain around 56% of the variation in maximum temperature, suggesting that there has been a generally steady tendency of rising or dropping temperatures through time.

The R^2 value for rainfall data is 0.13, which indicates a decreased linear relationship with time. Only 13% of the variance in rainfall can be explained by linear trends, indicating that non-linear patterns or other causes may have a greater influence on rainfall fluctuations.This implies that rainfall is less predictable based solely on a linear trend and might be subject to more complex dynamics.

The Mann-Kendall test statistic results (Table 3) shows the strength and direction of trends. For Minimum Temperature, a positive S value of 469 indicates a significant upward trend in temperature over time. Similarly, the Maximum Temperature also shows a positive S value of 451, signifying an increasing trend in maximum temperature. These results are consistent with the broader global climate change patterns and highlight the warming effect on temperature parameters. In the case of Rainfall, the positive S value of 187 indicates a statistically significant upward trend in precipitation levels. This increase in rainfall may have significant implications for regional water resources, agriculture, and ecosystems. The p-values obtained for all three parameters are less than the significance level ($\alpha = 0.05$), confirming the statistical significance of the trends. As a result, the null hypothesis of no trend is rejected, indicating the presence of significant trends in Minimum Temperature, Maximum Temperature, and Rainfall. The Mann-Kendall trend analysis of climatic parameters reveals statistically significant positive trends in Minimum Temperature, Maximum Temperature, and Rainfall. These findings reinforce the need for continued monitoring and research into climate change impacts and adaptation strategies. Policymakers and stakeholders should consider the implications of these trends to develop effective strategies for mitigating the adverse effects of climate change in the studied region. Further studies and long-term data collection are recommended to gain a

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

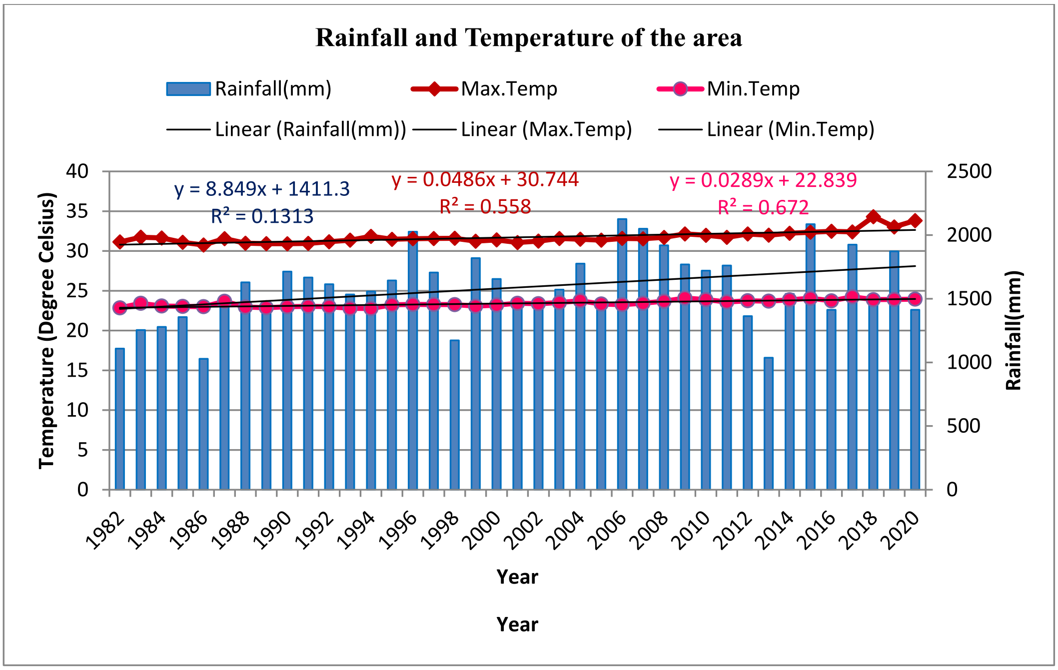

Fig. 2. climatic variations throughout the study period.

Table 3
Mann Kendall results for climate parameters.

Parameters	S	Z	P-Value	Trend
Minimum Temperature	469	5.70	0.00	+
Maximum Temperature	451	5.47	0.00	+
Rainfall	187	2.25	0.03	+

NB: Trend: (+) Positive Trend; (-) Negative Trend; () Random.

deeper understanding of the changing climate and its potential consequences.

Climate variability, as documented in a part of Nigeria, among several other places globally, can cause negative departures from the normal climate (Adejuwon, 2005). Rainfall is associated with SST, as equatorial Indian Ocean SSTs strongly influence rainfall variability in Nigeria in conjunction with the evaluate the influence of intertropical discontinuity (ITD), as the equatorial displacement of the Atlantic subtropical high suppresses the northward summer migration of the ITD, thereby resulting in rainfall variability (Bello, 2008).

The standardized anomaly index (SAI) of annual rainfall and temperature is shown in Fig. 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 (Fig. 3). The maximum temperature was above normal in the first and second decades (as the Standardized Anomaly Index is $>$ 1), moderate in the third decade and has increasingly furthered below normal since the fourth decade. 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. Cassava, yam, coco-yam, sweet potato, tomato, pepper, okra, maize, rice, cowpea, and melon crop production changes are depicted in Figs. 4, 5, and 6. These crops have respective trend values of 0.96, 0.33, 0.55, 0.91, 0.86, 0.81, 0.00, 0.10, 0.69, 0.46, and 0.80.

The result of Mann-Kendall trend analysis (Table 4) for crop yields revealed varying trends across different crops. While rice, melon, tomato, pepper, and okra exhibited statistically significant increasing trends, maize and cowpea showed no significant trends over the analyzed period. These results contribute to the existing literature on agricultural productivity and provide valuable insights for policymakers and stakeholders to develop targeted strategies for sustainable crop production and food security. Further research and longer datasets may be required to confirm and better understand the observed trends in maize and cowpea yields. Crop yields play a critical role in global food security and agricultural sustainability. Understanding the long-term trends in crop productivity is essential for informed decision-making and the formulation of effective agricultural policies.

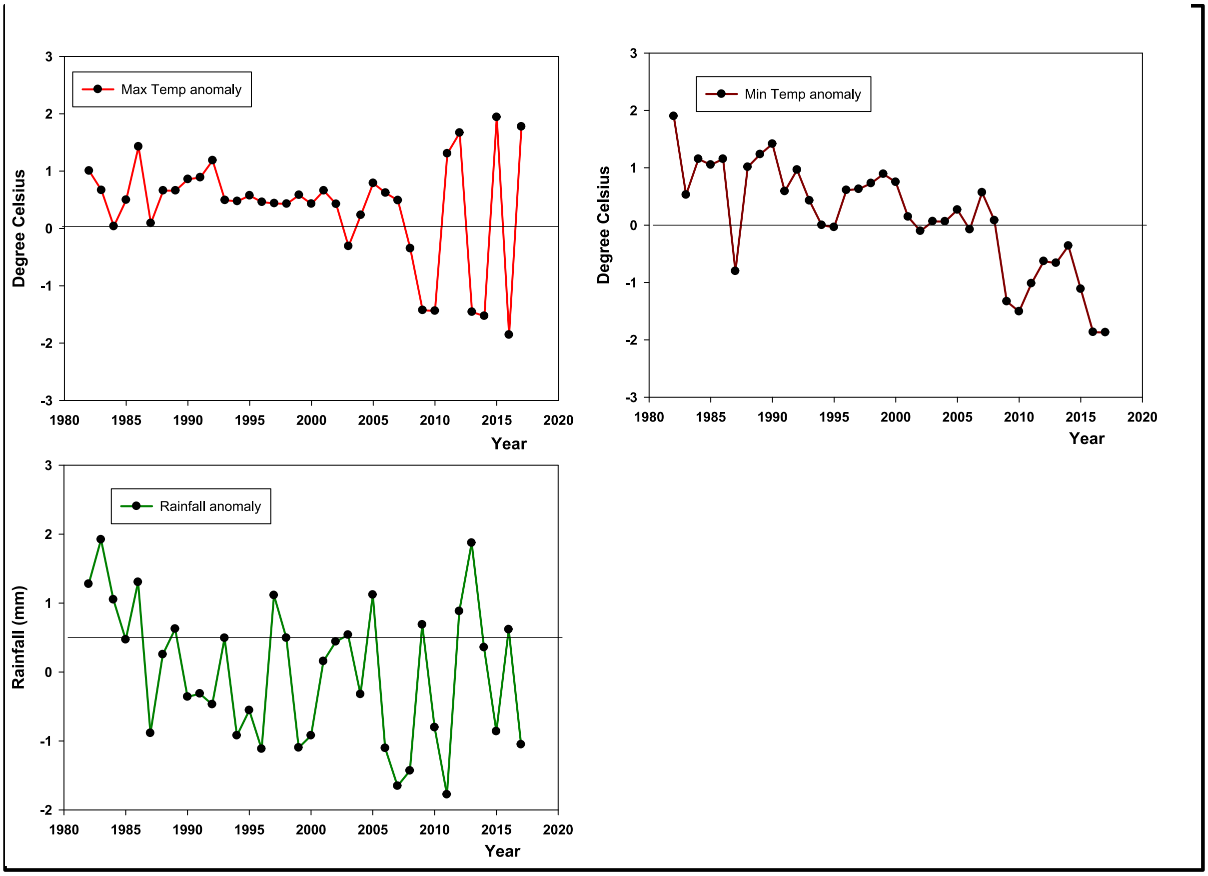

Fig. 3. Standardized Anomaly Index of climate parameters.

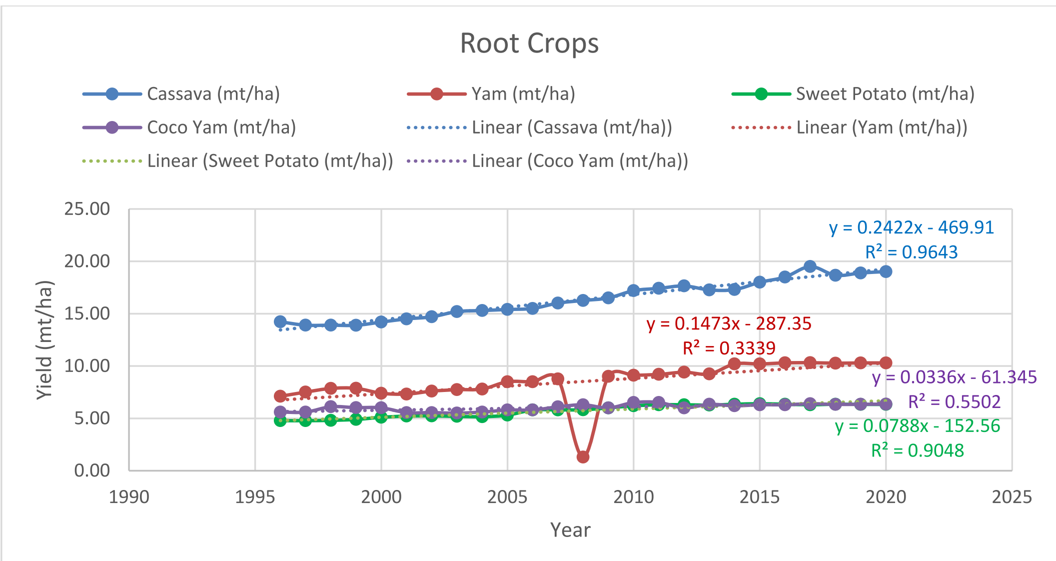

Fig. 4. Changes in the yield of root crops throughout the study period.

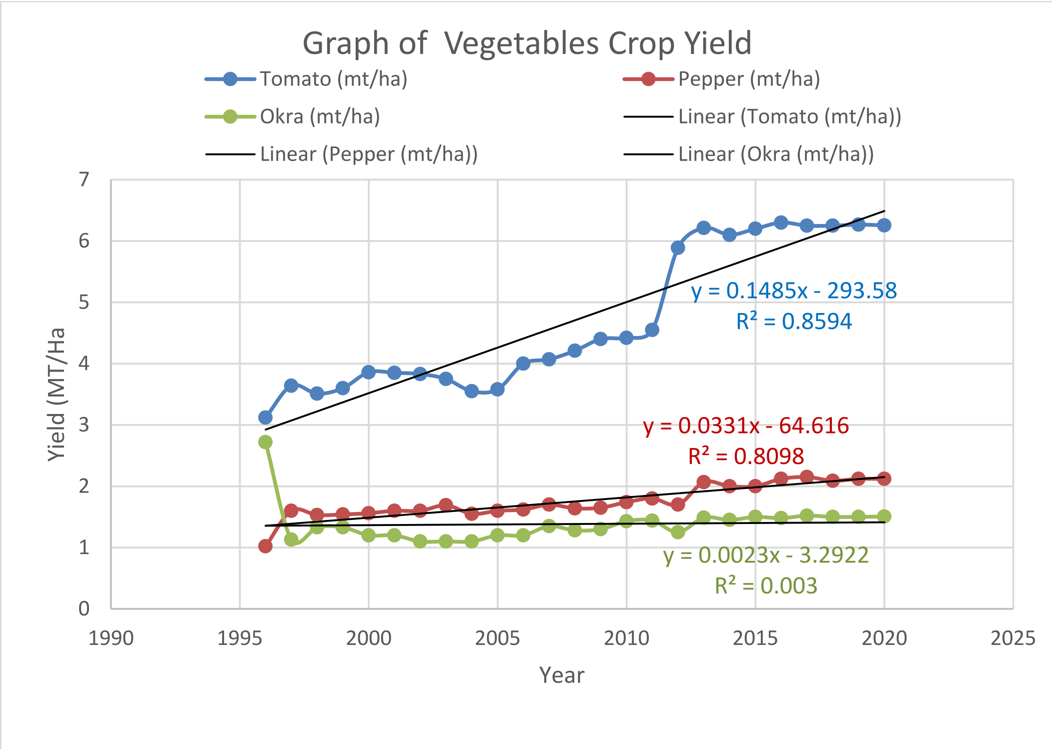

Fig. 5. Changes in the yield of selected vegetables over the study period.

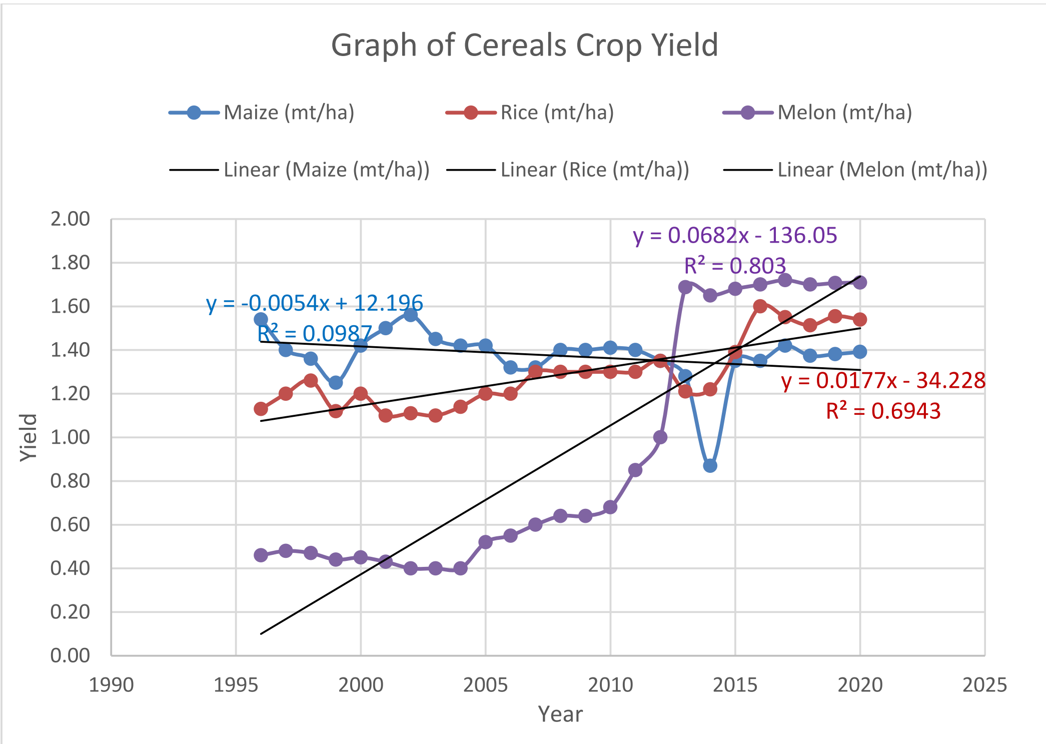

Fig. 6. Changes in the yield of cereals over the study period.

Table 4
Mann Kendall test for the selected crops.

Parameters	S	Z	P-Value	Trend
Maize	−80	1.86	0.06	
Rice	190	4.45	0.00	+
Cowpea	9	0.19	0.85	
Melon	224	5.22	0.00	+
Tomato	245	5.70	0.00	+
Pepper	245	5.72	0.00	+
Okra	206	4.83	0.00	+

Trend: (+) Positive Trend; (-) Negative Trend; () Random.

3.2. Relationship between climate and crop yields

Table 5 presents correlation result between different crops (Cassava, Yam, Sweet Potato, Coco-yam, Melon, Tomato, Pepper, Okra) and climate parameters (Rainfall, Maximum Temperature, Minimum Temperature). The correlations are accompanied by corresponding p-values. Cassava yield shows a significant correlation with rainfall ($r = 0.74$, $p = 0.05$), also it is positively correlated with maximum and minimum temperatures. Yam yield also shows significant correlation with rainfall, maximum and minimum temperatures. Sweet potato yield is positively correlated with both maximum and minimum temperatures, while coco-yam yield is also significant. From Table 3, yam and sweet potato have a significant correlation with rainfall, suggesting a strong linear relationship between rainfall and yam yield. However, higher temperatures are associated with increased yields of all the crops. Coco-yam also shows a positive correlation with both maximum and minimum temperatures, suggesting higher yield. Melon, tomato, and pepper also show significant positive correlations with both maximum and minimum temperatures, suggesting increased yield for these crops. Okra does not show significant correlations with any climate parameters. Overall, higher temperatures are generally associated with increased yield for these crops.

Thus, rainfall and temperatures are linked to increased Sweet Potato yield, while Cocoa-yam has low significant correlation with rainfall but shows positive correlations with Maximum and Minimum Temperatures. Melon, Tomato, and Pepper also show significant positive correlations with Maximum and Minimum Temperatures ($r > 0.70$, $p = 0.05$), suggesting increased yield for these crops. Okra does not show significant correlations with any climate parameters.

Regression results for crops are shown in Table 6, with coefficients of determination between crop yields and climate variables such rainfall, maximum temperature, and minimum temperature. The regression results demonstrates a strong positive linear association between climate variables and cassava yield, with a high coefficient of above 0.91. Generally, The regression is statistically significant and accounts for 83% of the variation in cassava yield. The coefficients of determination values for Sweet Potato, Melon, Tomato, and Pepper range from 0.64 to 0.74, with the high coefficients (R) ranging from 0.80 to 0.86. This results implies that climate variables account for 64% to 74% of differences in agricultural yield. These models' F-values are legitimate because they are statistically significant ($p < 0.05$). The link between climate variables and crop yield is poorer for yam and coco yam, which have lower correlation coefficients (R) and lower R-Square values. At $p < 0.05$, these models have F-values that are statistically significant.

The results suggest that the climate parameters have a stronger influence on the yield of crops like Cassava, Sweet Potato, Melon, Tomato, and Pepper, as evidenced by higher R-squared values and significant F-tests. In contrast, the relationship between climate parameters and the yield of Yam and Coco Yam appears to be relatively weaker, with lower R-squared values.. From the literature, it is evident that rainfall volume and frequency during the time immediately following planting affect yield, an increase in land committed to crop production may not result in a comparable increase in yield. Although, crops' sensitivity climate parameters at the start and end of the growing season differs (Amanambu et al., 2019, Ayanlade et al., 2020). There are also many other factors that can account for a reduction in crop 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 (Oseni and Masarirambi, 2011). 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 (Umar et al., 2014, Ayanlade, 2015, Ayanlade et al., 2020).

Table 5
Correlation between climate and crop yield.

	Rainfall		Max. Temp		Min. Temp	
Crops	Correlation	P-Value	Correlation	P-Value	Correlation	P-Value
Cassava (MT/Ha)	0.74**	0.05	0.80**	0.05	0.86**	0.05
Yam (MT/Ha)	0.66	0.05	0.53**	0.01	0.44	0.01
Sweet Potato (MT/Ha)	0.79**	0.05	0.68**	0.00	0.80**	0.05
Coco-yam (MT/Ha)	0.77**	0.05	0.58**	0.00	0.57**	0.05
Melon (MT/Ha)	0.48	0.05	0.80**	0.00	0.72**	0.01
Tomato (MT/Ha)	0.37	0.05	0.78**	0.05	0.759**	0.05
Pepper (MT/Ha)	0.31	0.01	0.72**	0.05	0.71**	0.05
Okra (MT/Ha)	0.26	0.05	0.22	0.05	0.0	0.01

NB: **= Significant at $p < 0.05$.

Table 6
Regression Result: climate influence on the yield of crops.

Crops	R	R-Square	Sum of Squares	Df	Mean square	F	P
Cassava	0.91	0.83	65.84	3	21.95	34.86	0.00
			13.22	21	0.63		
Yam	0.56	0.31	26.37	3	8.79	3.17	0.05
			58.17	21	2.77		
Sweet potato	0.82	0.68	6.07	3	2.023	14.854	0.00
			2.86	21	0.14		
Coco Yam	0.63	0.40	1.05	3	0.35	4.60	0.01
			1.60	21	0.08		
Melon	0.85	0.71	5.35	3	1.78	17.41	0.00
			2.15	21	0.10		
Tomato	0.86	0.74	24.72	3	8.24	19.97	0.00
			8.66	21	0.41		
Pepper	0.80	0.64	1.13	3	0.38	12.65	0.00
			0.63	21	0.03		

a. Dependent variable: Crops.
b. Predictors (Constant): Rainfall, Maximum Temperature, Minimum Temperature.

A strong relationship between temperature and crop yield is not surprising, previous studies have reported similar results (Monti and Venturi, 2007, Richards et al., 2002, Ayanlade et al., 2009). While rainfall variability is capable of influencing yield of cereals in general, 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 (Agbossou et al., 2012, Mawonike and Mandonga, 2017).

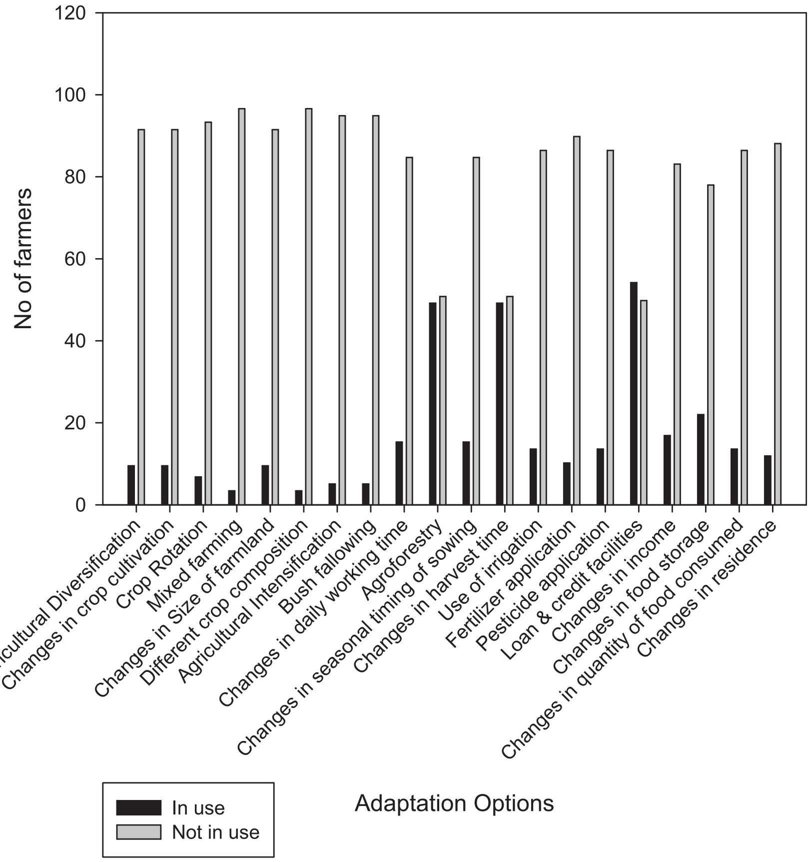

Fig. 7. Adaptation practice.

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 Fig. 7. From the results, agroforestry, changes in the time of harvest, using loan and credit facilities to farm are the most practiced adaptation options among the selected rural farmers.. 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 (Biesbroek et al., 2013).

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. From the result in Fig. 8 different forms of capitals including social, human and financial capitals are the major challenges hindering the practice of adaptation by many of the rural farmers.

In particular, the perceptions of climate change impacts, adaptation and barriers to adaptation methods vary by gender (Figs. 9 and 10). Generally, their adaptive capacity is low, although the most practiced adaptations were irrigation, use of loans and credit facilities, agricultural intensification, and agroforestry, among others. 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 (Fig. 9). 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 (Biesbroek et al., 2013, Oluwatimilehin and Ayanlade, 2021). 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 (Amanambu et al., 2019, Kogo et al., 2021). Climate change, market demand and societal change have led to different farmers abandoning some landrace crops.. 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 practises 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. Climate change impacts will be disproportionally harsh for the poorest countries and the most vulnerable people and groups, particularly women (UNDP, 2012). 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 Figs. 9 and 10.

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 (Shanahan et al., 2007, Odekunle et al., 2007). 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 (Choudhary et al., 2020, Han et al., 2019, Sniderman et al., 2019). Climate change has significant implications for global and regional food production, the extent of which is unknown to some extent because the impacts of climate variability on some common food crops, such as tubers, grains, legumes, and vegetables, vary as the mean temperature and moisture requirements vary with tuber crop production.

4. Conclusion

In this study, the observed impacts of climate change on crops were examined, and rural farmers' perceptions of climate, experiences, and adaptive capacity were assessed with the aid of a structured questionnaire. It was observed that the minimum and maximum temperatures were obvious with high variations, which also correlated strongly and positively with the yield of crops considered except okra. However, the study observed a general increase in the yield of some crops throughout the study, which is occasioned by fair practice of adaptation measures, especially the introduction of improved species that takes less time to maturity and are more tolerant 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.

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 (Maddison, 2007). 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

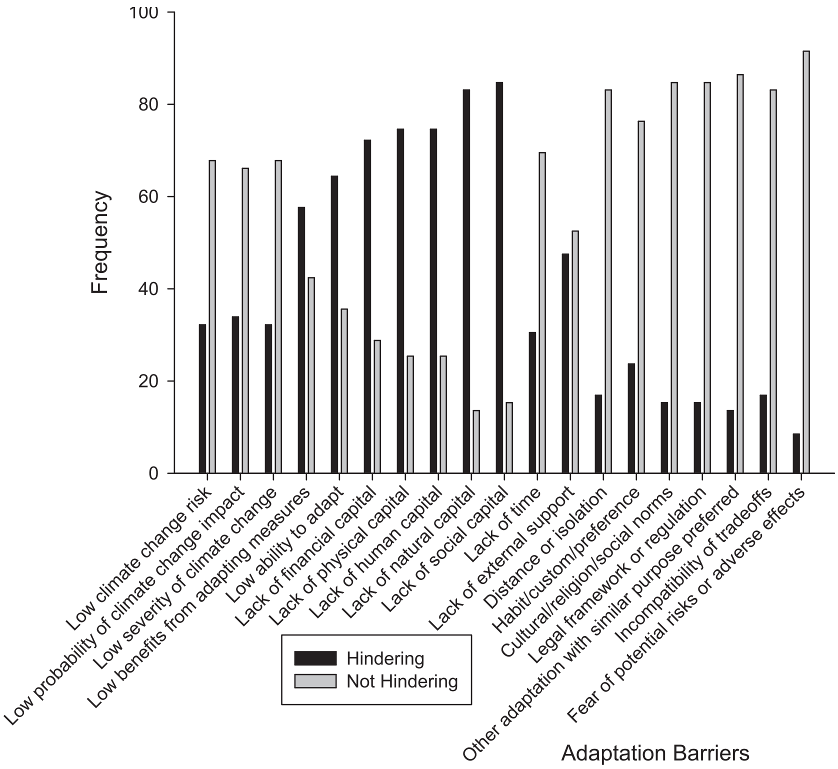

Fig. 8. Barriers to practice of adaptation.

markets, extension and credit services, technology and farm assets (land, labour and capital) are also effective adaptation measures and have been ongoing in Africa (Hassan and Nhemachena, 2008). Given the observations in this study, the following recommendations are made with regard to the impacts 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.

In Nigeria, the issue of boosting the output of staple crops is exacerbated by rising temperatures and unpredictability in rainfall. Farmers should have access to climatic information, as well as predictions and forecasts for farming seasons, in order to better prepare them for future uncertainty. 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.

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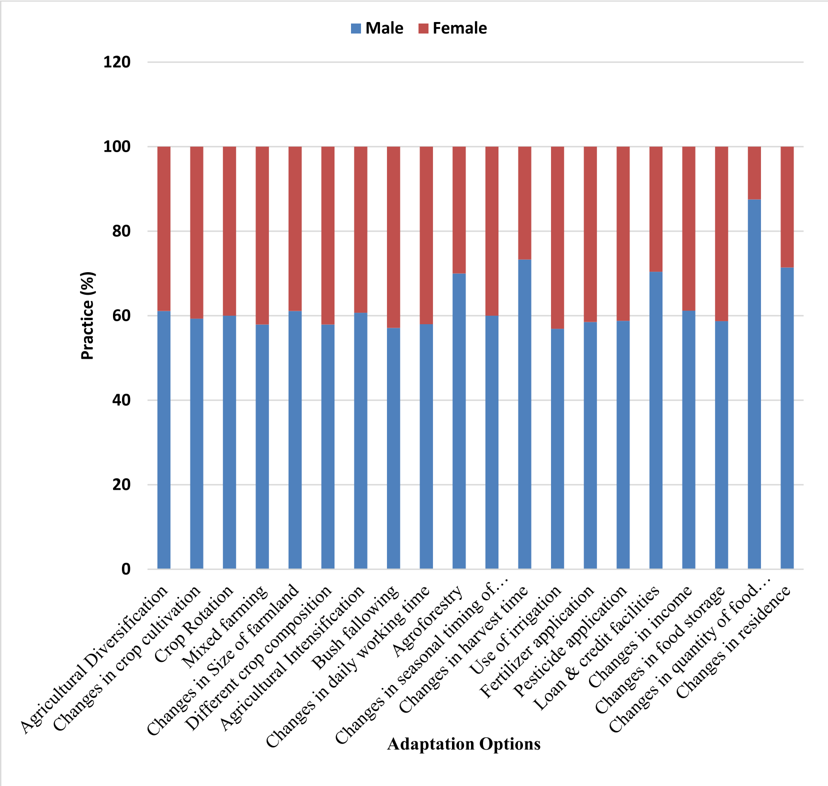

Fig. 9. Gender-based practice of adaptation.

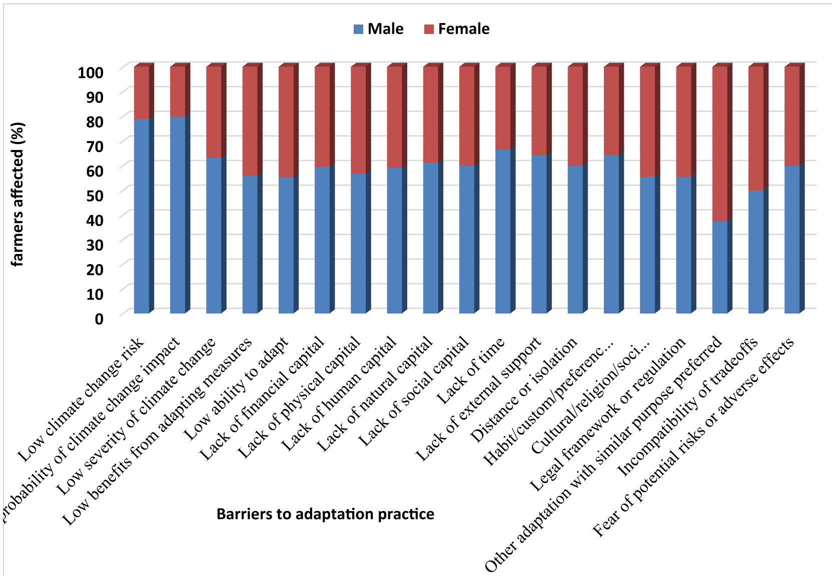

Fig. 10. Gender-based barriers to practice of adaptation.

Ethics approval/declarations

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 any way, data was processed in anonymous procedure, and survey participants had the possibility to skip questions.

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.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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