Climate Change Adaptation Options in Farming Communities of Selected Nigerian Ecological Zones

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Abstract

This chapter examines the impacts of climate change on three tropical crops and assesses the climate change adaptation options adopted by rural farmers in the region. The study was conducted among farming communities settled in three major ecological zones in Nigeria. Over 37 years of data on rainfall and temperature were analyzed to examine climate change impacts on three major crops: rice, maize, and cassava. Farmers' adaptive capacity was assessed with a survey. Climatic data, crop yields, and survey data were analyzed using both descriptive and inferential statistics. The relation between rainfall/temperature and crop

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yields was examined using the Pearson correlation coefficient. Results show a high variation in the annual rainfall and temperature during the study period. The major findings from this research is that crops in different ecological zones respond differently to climate variation. The result revealed that there is a very strong relationship between precipitation and the yield of rice and cassava at $p <0.05$ level of significance. The results further showed low level of adaption among the rural farmers. The study concludes that rainfall and temperature variability has a significant impact on crop yield in the study area, but that the adaptive capacity of most farmers to these impacts is low. There is a need for enhancing the adaptation options available to farmers in the region, which should be the focus of government policies.

Introduction

Given their impacts on both natural and human systems, climate variability and climate change have become topical issues in recent research. As the changing nature of weather and climate directly relates to crop yields, climate change impacts on the agricultural sector and food systems have been the focus of a growing number of works, including research in many African countries (Adenle et al. 2017; Morton 2017; Serdeczny et al. 2017; Molua 2020). Such studies have reported that rainfall and minimum and maximum temperatures are the most important climatic elements for agricultural production. The scenario over the years is that these climate parameters, especially rainfall patterns, have varied, with some high confidence of change in their patterns in recent years, as perceived through indigenous knowledge of people globally (Adejuwon 2005; Ayanlade 2009; Sowunmi and Akintola 2010; Moylan 2012; Adamgbe and Ujoh 2013; Pablo and Antonio 2015; Ayanlade et al. 2017). The multi-hazard events climate change occasions comprising of windstorms, wildfire, rainstorms, droughts, and dust storms which maybe become more frequent with increased severity in the nearest future. There are several pieces of evidence in the literature that land use and land cover change (Ayanlade 2017; Fourcade et al. 2019), sea-level rise (Agboola and Ayanlade 2016; Varela et al. 2019), and changes in onset will pose significant long-term challenges. There have been changes that can be identified by alteration in the mean or variability of climate properties and that have persisted for an extended period. Consequently, climate change will pose imperative short-term and long-term bottlenecks to agricultural production, particularly for rural farmers who depend on rainfall for cultivation (IPCC 2007; Heltberg et al. 2009; Ayanlade et al. 2018b; Ayanlade and Ojebisi 2020).

Agriculture is vulnerable to climate change as crops are sensitive to rising temperatures and changing rainfall patterns. Rising temperatures and erratic rainfalls threat food crop production, thus exacerbating food insecurity and poverty (Sanchez 2000;

Oluoko-Odingo 2011; Seaman et al. 2014). The impacts of climate change on agriculture are likely to intensify in the future as climate models have predicted increasing temperature and more erratic rainfall with the potential increase in the intensity and frequency of extreme weather events (Wright et al. 2014; Ayanlade et al. 2018a; Hein et al. 2019). For example, some studies have suggested that climate change will reduce the yield of crops like maize, rice, and cassava by 15–25%, partly because climate change will alter the incidence and severity of pest and disease outbreaks, indirectly affecting crop production and yield (Harvey et al. 2018). Even though climate change portends serious dangers to agriculture, current studies on climate change impacts on the agricultural systems of Nigeria suffer from several gaps. First, previous studies have mostly focused on crops like yam, coffee, cocoa, sorghum, etc. (Ayanlade 2009; Ayanlade et al. 2009; Ajetomobi 2016). Other studies on the topic have used short-term data, although long-term data is more accurate in delineating climate change effects on agricultural practices (Adejuwon 2005, 2012). Thus, previous research on this topic has treated Nigeria as a single ecological zone. To fill these gaps, the present study focuses on climate change impacts on three crops that have not previously received attention (i.e., rice, maize, and cassava) and using data from three (3) different states in Nigeria, falling within three different ecological zones: Ondo (Rainforest), Ogun (Freshwater), and Kwara state (Guinea savanna). This spread will importantly give room for spatiotemporal comparison. More so, this study involves the indigenous knowledge of climate change, effects, impacts, and adaptation practices among the rural farmers. Rural farming is very important in this part of the world for the provision of food and productive employment for many people.

Climate Change Assessment in Selected Ecological Zones in Nigeria

Research as conducted in three different sites (Fig. 1), representing three different ecological zones: Ondo (rainforest located within latitude 7°10′N, 7°15′N and longitudes 5°5′E and 5°83′E); Ogun (freshwater, located between on latitude 6°12′N and 7°47′N and longitude 3°0′E and 5°0′E); and Kwara (savanna, located between latitude 7°45′N and 9°30′N and longitude 2°30′ and 6°25′E). The three sites fall within the tropical wet and dry climate of Koppen's climate classification, dominated by a wet and a dry season. There are, however, some variations between sites. The climate of Ondo State corresponds to a lowland tropical rain forest type, with a mean monthly temperature ranging from 19 °C to 30 °C (mean monthly value of 27 °C) and a mean relative humidity 75% (Owoeye and Sekumade 2016). The mean annual total rainfall exceeds 2,000 mm. In the northern part of the state, there is marked dry season from November to March with little or no rain, for which the total annual rainfall in the north is of about 1,800 mm (Jamie 2016). Differently, Ogun state is characterized by a tropical climate consisting of two distinct wet and dry seasons. The long dry season extends from November to March. The annual rainfall value ranges between 1,400 and 1,500 mm with a relatively high temperature of an average of 30 °C. The average temperature value varies from one month to another,
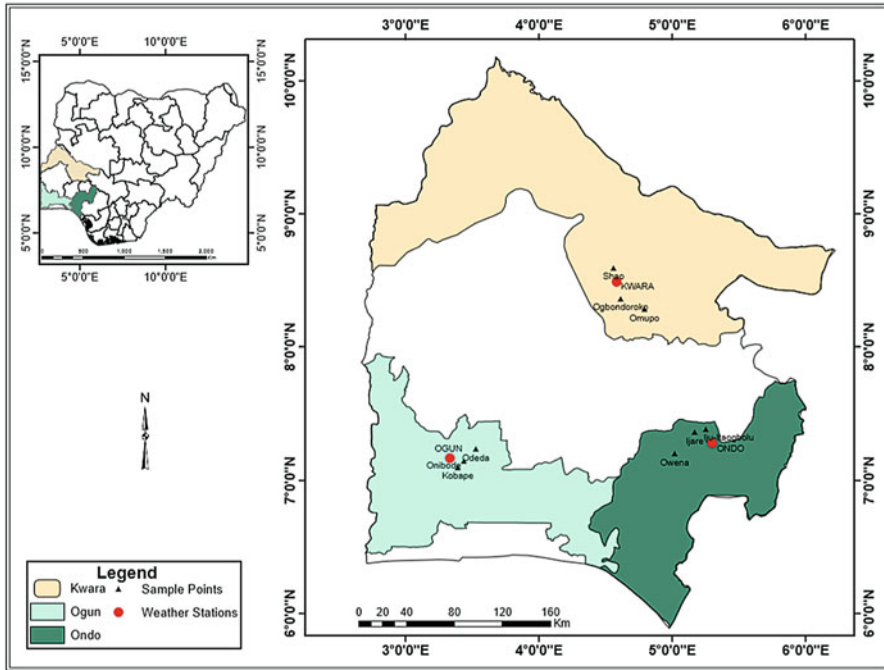
Fig. 1 Study area: Ondo, Ogun, and Kwara states in western Nigeria

with a minimum average of 25.7 °C in July and a maximum of 30.2 °C in February. The humidity is lowest at the peak of the dry season in February usually at 37–54% and highest between June and September with a value of 78–85% (Adeleke et al. 2015). Kwara state (Oladimeji et al. 2015) enjoys an annual rainfall ranging from 1,000 mm to 1,500 mm with the rainy season beginning at the end of March and lasting until September while the dry season starts in October and ends in March (Oriola et al. 2010). The temperature of the state is uniformly high and ranges between 25 °C and 30 °C throughout the wet season except for July and September in which the cloud cover prevents direct insolation. In the dry season, the temperature ranges between 33 °C and 34 °C. In the rainy season, the relative humidity in Kwara state ranges between 75% and 80% while in the dry season it is about 65% (Akpenpuun and Busari 2013).

Ondo is an agrarian state with large-scale production of crops like cocoa, yam, cocoa, coffee, and rubber and huge forest reserves of about 2,008 km^2 which produce timbers for furniture, fuelwood, and industrial uses. Ogun is also an agrarian state with the production of arable crops like maize, rice, cassava, and melon. Several other identifiable modern economic activities exist in Ogun, including insurance, motor companies, petrol stations, and light and heavy industries. The major economic activity of Kwara state is farming, with a particular predominance of cash crops like cocoa, coffee, kolanut, tobacco, beniseed, and palm. Food crops like cereals (rice, maize, millet) and tuber crops (yam, cassava, cocoyam, etc.) are grown in Kwara (Oluwasusi and Tijani 2013).

Daily climatic data of rainfall and minimum and maximum temperatures were used for this study. The data, spanning for a period of 37 years (1982–2017), were collected from the synoptic stations (Fig. 1) located at Akure (Ondo state), Ilorin (Kwara state), and Abeokuta (Ogun state). The data were collected by the Nigerian Meteorological Agency (NIMET) at the stations using the British Standard Rain gauge and Dine's tilting siphon rainfall recorder for rainfall and thermometer for temperature. To establish the pattern of climate, a year running mean was used in the analysis to show the annual fluctuation of rainfall and temperature. Mean of daily data were averaged to get the annual mean for temperature (minimum and maximum) and rainfall using MS Excel. Sigma Plot (Version 10.2) was used to plot the graph for annual rainfall, and minimum and maximum temperature against the year covering the study period; the curves were then fitted to show the linear trend. Three crops, that is, maize (cereal), rice (cereal), and cassava (tuber), were used for this study. In this research, climate factors are seen as one of the important requirement for the yield of the crops, as normal seasonal water requirements of maize, for example, is between 400 and 600 mm (Phiri et al. 2003). Maize and rice are common crops in all three zones. Crop yield data were obtained from the archives of Agricultural Development Project (ADP) offices in Ondo, Ogun, and Kwara states. Data were analyzed using the Pearson correlation coefficient between crop yields and climatic data. This was done using the formula below:

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

where N is the number of pairs of scores, $\sum xy$ is sum of the products of paired scores, $\sum x$ is sum of scores, $\sum y$ is sum of y scores, $\sum x^2$ is sum of squared x scores, $\sum y^2$ is sum of squared y scores, x is the crop yield, and y is the climate data.

Social survey data for the study were collected from farmers with the aid of questionnaires and focus group discussion. Our survey instrument was designed to assess farmer's adaptive capacity. Data were collected among farmers who are purposively selected across the three states under consideration. Criteria for inclusion in our sample were to be in a settlement where maize, rice, and cassava are cultivated and to be 30 years and above. These criteria ensured the collection of data among experienced farmers who had witnessed different farming seasons. The responses from the questionnaires were analyzed using both descriptive and inferential statistics. The major aim of social survey is to obtain information from the farmers on how the yields have been over the years and compare it with changes in climate.

Annual Variability in Rainfall and Minimum and Maximum Temperature

Rainfall data for a 37 years period revealed a variation in the annual mean amount of rainfall (Fig. 2). Rather than an absolute change, results for all the three stations show rainfall variability. The rainfall in Kwara is below normal, a little above normal
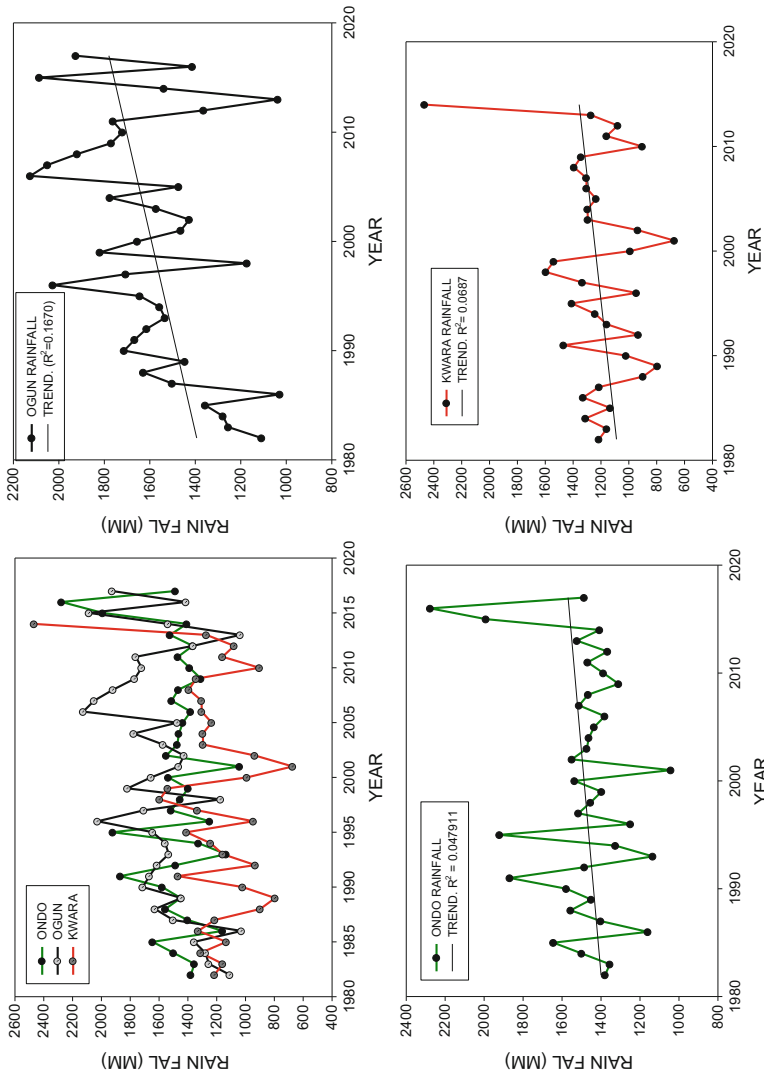
Fig. 2 Rainfall variability in the study area

in Ogun, and varied in Ondo. The rainfall variability found in the data can be attributed to seasonal and interannual climatic variability, which is much more several particularly in the savannah region where Kwara is located (Adejuwon 2004; Odekunle et al. 2007; Ayanlade 2009). As depicted in Fig. 2, annual rainfall was mostly below average before 2010, but varies greatly in the last decade, with readings above average in all the stations. Rainfall peaked in 1991 (with 1,982 mm) and 1995 (1,999 mm) in Ondo state, with 2016 (2,206 mm) recording the highest rainfall during the study period (Fig. 2). In Ogun state, rainfall peaked in 1996 (2,026 mm), 2006 (2,216 mm), and 2015 (2,086 mm), with 2006 recording the highest rainfall. Finally, in Kwara, rainfall peaked in 1991 (1,468 mm), 1995 (1,409 mm), 1998 (1,596 mm), and 1999 (1,539 mm), with the highest peak recorded in 2014 (2,467 mm) with a very unusual high value. Generally, the annual average of rainfall was lowest (673 mm) in Kwara state, with similar values in Ogun (1,028 mm in 1986 and 1,037 mm in 2013) and Ondo states (1,041 mm). Values follow an expected pattern, with higher values in the rainforest ecological zone close to the ocean and lower values in inward zones closer to the savanna. Ogun state received the highest rainfall between 1995 and 2010. The highest rainfall within a year was recorded in 2014 in Kwara, the state belonging to Guinea savanna ecological zone, which recorded a value slightly above the peak of rainfall in Ondo (which belongs to the forest ecological zone).

Climatic variability in the study area can be linked to global climate oscillating systems as El Niño – Southern Oscillations, sea surface temperatures (SSTs), and Inter-Tropical Discontinuity (ITD) have been reported to be responsible for inter-annual variability in Africa climate (Stige et al. 2006). Such climate variability can cause negative departures from normal climate, as documented in a part of Nigeria and elsewhere (Ashipala 2013; Owusu et al. 2015; Ayanlade et al. 2018a). Studies have further revealed that rainfall associated with SST strongly influences 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 into rainfall variability (Bello 2008; Ayanlade et al. 2019).

High variability was observed in the maximum temperature of all stations between 1982 and 2017 (Fig. 4). The temperature was highest in Kwara state, the northernmost state which falls within the Guinea savanna – an area dominated with relatively low rainfall and high temperature – and lowest in Ondo state, the south-ernmost state. Ondo and Ogun state recorded temperatures below average between 1982 and 2010. However, temperatures have experienced an increase from 2012 till date, especially in Ogun state with the temperature higher gradually increases. As shown in Fig. 3, all the stations experienced similar minimum temperatures patterns from the early 1980s. Temperature oscillations in the maximum temperature were recorded between 1990 and 2010 in Ondo and Ogun with an upward trend observed only in Kwara, though from 2010, the temperature has generally increased in all stations (Figs. 3 and 4).

As shown in Fig. 3, the annual minimum temperature is highest in Ogun state with the lowest value in 1994 (22.8 °C), a value that coincides with the highest
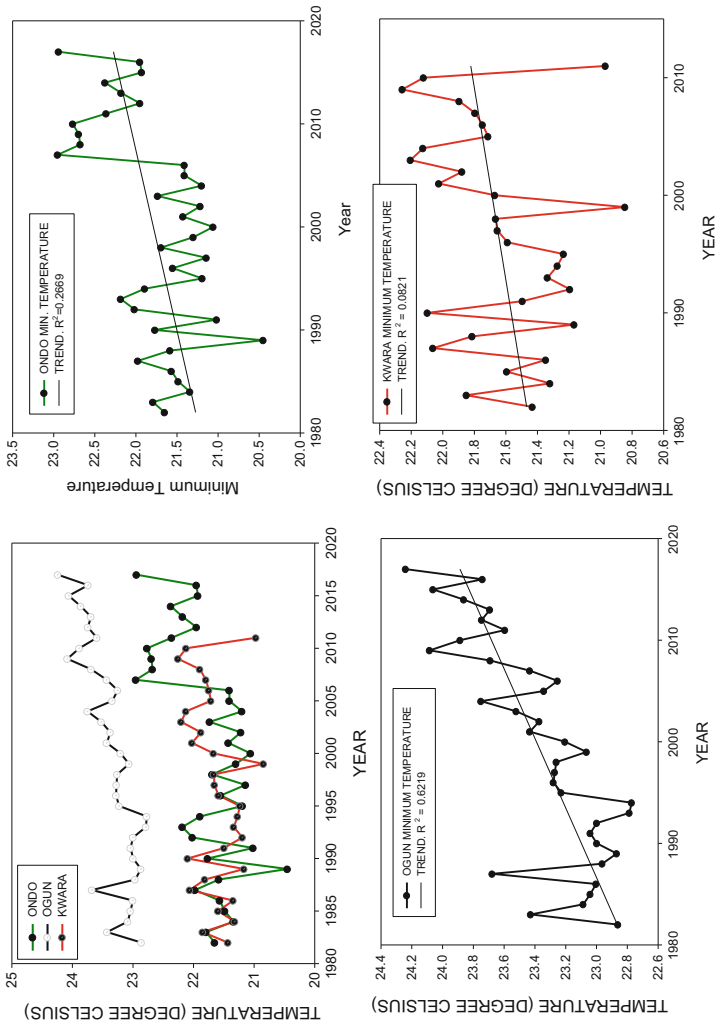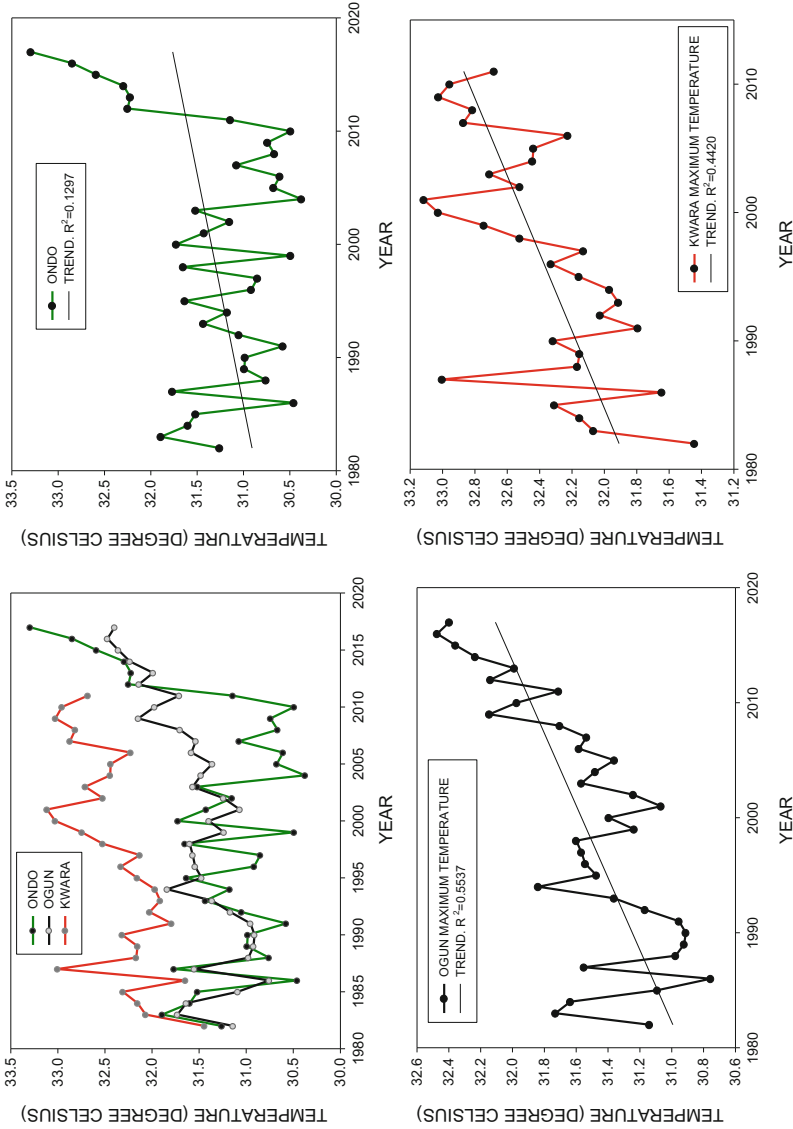
Fig. 3 Minimum temperature variability

Fig. 4 Maximum temperature variability

minimum temperature in Ondo state. Despite the southern location of Ogun state, the minimum temperature is generally above the minimum temperature for the other two stations, among which Ondo displays the lowest temperature than Kwara. These values represent the highest temperature difference in Kwara and the lowest temperature difference in Ogun state. The period of temperature increase in Kwara state (i.e., years 2000, 2001, and 2002) corresponds to the period of rainfall decrease which could be attributed to increasing temperature and decreasing rainfall as a result of the increasing evapotranspiration and desertification also reported in other areas of Nigeria (Ayoade 2003). The trend of the maximum temperature varies considerably in all stations. However, while the trend is irregular in the early years of the study period, an upward increasing trend was observed in the later years. This recent increase in temperature could be linked to the effect of changes in climate and to the rapid urbanization in the ecological zones under consideration (Mabo 2006).

Relationship Between Climate and Crop Yield

The results of the Pearson correlation analysis between annual minimum temperature and crop yields during the growing season are shown in Table 1. Annual minimum temperature had positive but weak correlation with maize in Ondo (0.142) but not significant at $p < 0.05$, a weak and not statistically significant negative correlation of -0.078 at $p < 0.05$ in Ogun state, and a positive correlation of 0.219 in Kwara at $p < 0.05$. Rice, on the other hand, had a positive but weak correlation of 0.167 which is statistically not significant at $p < 0.05$ in Ondo state while in Ogun state with a positively strong and statistically significant correlation coefficient of 0.674 at $p < 0.05$ and a strong positive and statistically significant correlation coefficient of 0.481 in Kwara state at $p < 0.05$. The correlation coefficient for cassava in Ondo state is a weak and statistically not significant value of 0.22 at $p < 0.05$ while a strong positive and statistically significant correlation coefficient of 0.82 at $p < 0.05$ in Ogun and a positive but not significant correlation of 0.25 at $p < 0.05$. Generally, annual minimum temperature had a strong, positive, and statistically significant correlation coefficient at $p < 0.01$ and $p < 0.05$ in rice for Ogun and Kwara states and cassava only in Ogun state.

Table 2 shows the result of Pearson correlation analysis between annual maximum temperature and crop yields during the study period. The annual maximum temperature had a positive weak and statistically not the significant relationship with maize in Ondo (0.198) at $p < 0.05$, a weak and not statistically significant negative

Table 1 Correlation between minimum temperature and crop yield

	Maize	Rice	Cassava
Ondo	0.142	0.167	0.220
Ogun	−0.078	0.674[*]	0.820[*]
Kwara	0.219	0.481[*]	0.248

[*]Significant at $p < 0.05$

Table 2 Correlation between maximum temperature and crop yield

	Maize	Rice	Cassava
Ondo	0.198	0.160	−0.115
Ogun	−0.337	0.884**	0.870**
Kwara	0.342	0.773**	0.626**

*Significant at $P \leq 0.05$; **Significant at $P \leq 0.01$

Table 3 Correlation between rainfall and crop yield

|	Maize	Rice	Cassava
Ondo	−0.151	−0.091	−0.076
Ogun	0.003	0.136	0.046
Kwara	0.08	−0.220	0.064

*Significant at $P \leq 0.05$; **Significant at $P \leq 0.01$

correlation of −0.337 at $p < 0.05$ in Ogun state, and a positive correlation of 0.342 in Kwara at $p < 0.05$. Rice had a positive but weak correlation of 0.160 which is statistically not significant at $p < 0.05$ in Ondo state while in Ogun state with a positive, very strong, and statistically significant correlation coefficient of 0.88 at $p < 0.05$ and a very strong positive and statistically significant correlation coefficient of 0.77 in Kwara state at $p < 0.05$. The correlation coefficient for cassava in Ondo state is a negative, weak, and statistically not significant value of −0.12 at $p < 0.05$ while a very strong positive and statistically significant correlation coefficient of 0.87 at $p < 0.05$ in Ogun. A positive and significant correlation of 0.63 at $p < 0.05$. Generally, the annual maximum temperature had a strong, positive, and statistically significant association with rice and cassava yields in Ogun and Kwara states but not in Ondo state. The maximum temperature was not associated with maize yields in any of the states.

The result of the Pearson correlation analysis between annual rainfall and crop yields during the study period is shown in Table 3. Annual rainfall had a negative, weak, and statistically not a significant relationship of −0.15 with maize Ondo at $p < 0.05$, a weak and not statistically significant positive correlation of 0.003 at $p < 0.05$ in Ogun state and a positive correlation of 0.08 in Kwara at $p < 0.05$. Rice showed a negative but weak correlation of −0.091 which is statistically not significant at $p < 0.05$ in Ondo state while in Ogun state with a positive, weak, and statistically significant correlation coefficient of 0.14 at $p < 0.05$ and a weak, negative, and statistically not significant correlation coefficient of −0.22 in Kwara state at $p < 0.05$. The correlation coefficient for cassava in Ondo state is a negative, weak, and statistically not significant value of −0.08 at $p < 0.05$ while a positive and statistically not significant correlation coefficient of 0.046 at $p < 0.05$ in Ogun was observed. And a positive, weak, and not the significant correlation of 0.06 at $p < 0.05$ was observed for Kwara state. Generally, annual rainfall had a weak and statistically not significant association with maize, rice, and cassava yields in the three studied states.

Farmer's Adaptive Strategies

Figure 5 shows the percentage error graph of farmers' coping or adaptive capacity toward extreme climatic conditions. According to our results, 16.7% of the respondents are engaged in agricultural diversification, 17.3% are engaged in changing the crops they cultivate, 20.2% are engaged crop rotation, and 19.6% are practicing mixed farming.

As shown in Fig. 5, the farmers are coping or adapting to extreme climatic conditions but generally with low capacity. This is because the results show that 19% of farmers had implemented changes in the size of farmland, 14.9% are engaged in different crop composition, 33.3% are engaged in agricultural intensification, 30.4% are engaged in bush fallowing, 29.8% are changing the daily working time, 47.6% are presently engaged in agroforestry, 27.4% are changing the seasonal timing of sowing, 41.1% are changing the harvest time, 35.7% are into irrigation, 31.5% are into the use of fertilizer, 32.1% are into the use of pesticide, 56.5% are into getting loan and credit facilities, 32.7% are into getting other sources of income so as not to depend on their farm only, 44% are changing the method of storing their food, 27.4% are changing the quantity of food consumed by the family, and 24.4%
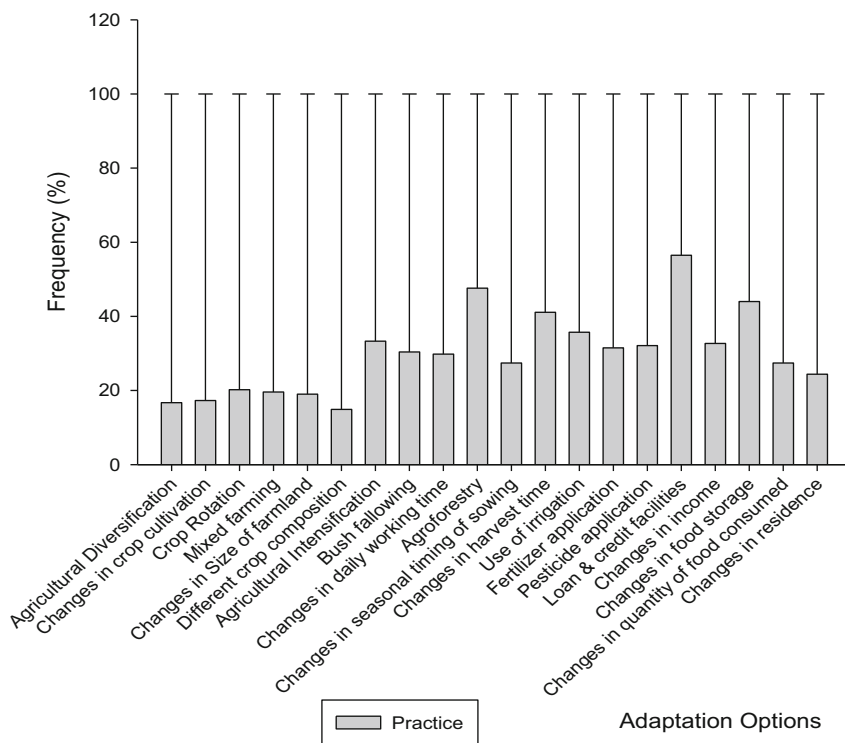
Fig. 5 Adaptation strategies adopted by farmers in the region

are changing their residence by moving to another area for farming. From Fig. 5, seeking for loans and credit facilities, changes in food storage, agroforestry, changing the time of harvest, use of irrigation, use of fertilizer, and agricultural intensification, among others, are the most practiced adaptation options.

Conclusion

The effects of climate variability or climate change on selected crops in selected ecological zones in Nigeria were examined in this study. Results show that minimum temperature, maximum temperature, and rainfall varied both spatially and temporally. The annual minimum temperature, maximum temperature, and rainfall showed that there is the year-to-year fluctuation with pronounced peaks and depressions. While some years show upward trends, some showed a downward trend. Also, there is the month to month variability in minimum temperature, maximum temperature, and rainfall. Crop yields did not depend on rainfall and minimum and maximum temperatures alone. In all the stations, maize yields were less sensitive to minimum temperature than rice and cassava yields. While there appears a negative but weak relationship that is not statistically significant between minimum temperature and maize in Ogun, it has a positive but weak relationship in Ondo and Kwara. Maximum temperature showed a strong positive and statistical association with rice and cassava yields in Ogun and Kwara states. Finally, rainfall was associated with maize, rice, or cassava yields in any state. Many other studies have reported the similar finding of the climate-crops relationships in China (Zhang et al. 2016; Gao et al. 2019; Ding et al. 2020), Southern Africa (Mafongoya et al. 2017; Nhamo et al. 2019) and East African countries (Sridharan et al. 2019; Thomas et al. 2019). These results dovetail with results from previous research. Thus, although an increasing trend in rainfall and temperature may affect rice yields, a study in Bangladesh showed that despite an increasing rainfall and temperature, the yield of rice is not negatively affected (Rahman et al. 2017). Matched with the results of the present study, the rainfall can, therefore, have a positive or negative impact on the yield of crops depending on its distribution and intensity over the growing season. Furthermore, the present study revealed that farmers' perception of climate variability/change impacts on crop yield varied spatially. The majority of farmers believed that average temperature of the coldest month, rain generally, rain during the rainy season, and rain during the dry season were believed to have changed in recent years in Ogun and Kwara by higher numbers of respondents, while statistical analyses showed that there is variation while in Ondo state, the farmers believe that "the temperature is warmer generally, the temperature of the hottest season is warmer, rain is higher in the rainy and dry seasons with extreme drought less frequent, onset earlier, rainy season duration longer." The temperature of the hottest month was believed, though, to be warmer by a higher proportion, as claimed by the farmers. Many believe that extreme floods are more frequent while extreme drought and duration of the rainy and dry seasons have remained the same. According to Tripathi and Mishra (2017), farmers are aware of long-term changes in climatic factors

(temperature and rainfall) but are unable to identify those changes as climate change. However, many farmers are not taking concrete steps in dealing with perceived change in climate but are changing their agricultural and farming practices (Ayanlade et al. 2018a) which can be said to be passive response to climate change. Farmers' perception of climate is probably responsible for low adaptation to climate change.

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