Climate Change

Historical analysis of climate variability and agricultural production in Nigeria (1931-2020)

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ABSTRACT

This paper investigates the historical relationship between climate variability and agricultural production in Nigeria from 1931 to 2020. Agriculture, employing around 70% of the workforce and significantly contributing to GDP, is a cornerstone of Nigeria's economy but is highly vulnerable to climate variability. The study employs a mixed-methods approach, integrating quantitative data analysis with qualitative assessments to explore the impacts of temperature, precipitation, and extreme weather events on major crops. Historical climate data was sourced from the Nigerian Meteorological Agency (NIMET), and agricultural production statistics were obtained from the Food and Agriculture Organization (FAO) and the Nigerian Bureau of Statistics (NBS). Findings reveal significant correlations between climatic factors and agricultural yields. Temperature records show a gradual increase over the study period, with notable spikes in the late 20th and early 21st centuries. Rainfall data indicates significant variability, with periods of drought interspersed with heavy rainfall events increasing in recent decades, affecting agricultural cycles. Statistical analysis highlights that maize, sorghum, and millet yields are particularly sensitive to these climatic changes. For instance, maize yields declined by over 20% during the droughts of the 1970s and 1980s. Qualitative insights from historical narratives and case studies illustrate the diverse impacts of climate variability across different regions of Nigeria. In northern Nigeria, the Sahelian droughts led to significant declines in sorghum and millet production, while in southern regions, excessive rainfall often caused flooding, impacting cassava and yam production. Farmers have historically employed adaptive strategies, including crop diversification, irrigation, and soil management practices. The study underscores the necessity for robust climate adaptation policies to mitigate adverse effects on agriculture. Policy recommendations include promoting climate-resilient crop varieties, enhancing irrigation infrastructure, and implementing early warning systems for extreme weather events. The findings highlight the critical need for adaptive strategies to ensure the sustainability of Nigeria's agricultural sector amid on-going climatic changes.

Keywords: Climate variability, agricultural production, Nigeria, historical analysis, climate change, sustainable agriculture.

1. INTRODUCTION

This study provides a comprehensive historical analysis of the impacts of climate variability on agricultural production in Nigeria from 1931 to 2020. It explores the intricate relationship between climatic factors such as rainfall, temperature, and extreme weather events, and the productivity of major crops in Nigeria. Utilizing historical climate data and agricultural production records, this paper identifies significant trends and anomalies in climate patterns and correlates these with fluctuations in agricultural output. The findings reveal that climate variability has had profound effects on agriculture, necessitating adaptive strategies to ensure food security in the face of ongoing climatic changes.

Climate variability has been a focal point of agricultural research for decades due to its profound impacts on food security, economic stability, and social well-being. In Nigeria, a nation heavily reliant on agriculture, the interplay between climate and agricultural production has significant implications for development and sustainability (Ayinde et al., 2011). This study aims to conduct a comprehensive historical analysis of climate variability and its effects on agricultural production in Nigeria from 1931 to 2020, a period marked by substantial climatic fluctuations and agricultural transformations.

Nigeria's climate-agriculture relationship is intricate and multidimensional. Because most of Nigeria's agriculture is rain-fed, it is highly dependent on changes in the weather (Adejuwon, 2004). It is necessary to have an in-depth understanding of the local climate dynamics and their agricultural implications because the country's distinct vegetation zones, which span from the humid south to the arid north, demonstrate different responses to climatic changes (Oladipo, 1993). There is no place in the world where precipitation (rainfall) influences people's way of lives than in the tropics. Here, rainfall does not only affect the agricultural sector, but it also impacts on the things people do and when they do it. Climate imposes cost on man; however, it also bestows benefits on them.

For instance, storms, drought and floods which are products of extreme climate and weather causes damage to crops and sometimes loss of life, but the day-to-day variations in weather and the seasonal variations of climate contributes to the rich variety of flora and fauna, which add so much to the quality of lives and environment (Alexander, 2015; Chinago, 2020). Historical climatic data provides valuable insights into long-term trends and patterns. Nicholson, (2001) emphasized the importance of historical climatology in understanding present and future climate scenarios. His work on the West African climate revealed significant shifts in rainfall patterns and temperature over the past centuries, which are crucial for contextualizing current climatic conditions.

Such historical perspectives are vital for developing adaptive strategies to mitigate agricultural adverse impacts (Boko et al., 2007). Analysis of historical climate and agricultural data over years will possibly generate a long-term pattern that will chart or define the agricultural development in relationship to climate over Nigeria. Historical climatology is crucial to comprehending both current and projected climate scenarios, according to (Nicholson, 2001). Significant changes in temperature and rainfall patterns during the previous few centuries was observed in the West African climate, and these findings are essential for understanding the current state of the region. These historical viewpoints are crucial for creating adaptive techniques that lessen adverse effects on agriculture (Boko et al., 2007).

Nigerian agriculture has been affected by significant climatic events that occurred between 1931 and 2020. For example, the 1970s and 1980s had extreme droughts, especially in the Sahelian region, which had a disastrous impact on livelihoods and agricultural output (Mortimore, 1989). These droughts demonstrated how dependent Nigerian agriculture is to climate extremes and the necessity of effective adaptation strategies. It is believed that agriculture is a gamble on the vagaries of nature, because, unlike in the temperate region, the tropical people's agricultural calendar is determined by the onset of rainfall; therefore, seasonal rainfall dictates not only the planting period but also the harvesting season (Alexander, 2012; Alexander, 2015; Ayoade, 2004).

Various scholars have pointed out the importance and reliability of Nigerian agriculture in relation to climatic elements. For instance, Olaniran and Summer, (1989) stated that variation in rainfall patterns affects crop yield in Nigeria, especially in the savannah zones. Ologunorisa, (2009) observed that climatic elements, such as rainfall and temperature impacts on the length of growing seasons, water availability, and incidence of pests and diseases, which collectively affects agricultural productivity in the study area. Budnuka et al., (2015), Chinago and Weli, (2022) and Ayoade, (2004) attested to the fact that climatic elements variability and fluctuation over time and space are great challenges to agricultural productivity.

The variability of the elements of climate, especially, precipitation and temperature is not just a challenge to agricultural sector in Nigeria economy, but also challenging to those depending on it for income, raw materials and for food. Socioeconomic variables and climate variability interact to affect agricultural output and practices. Nigerian farmers' strategies for adaptation demonstrate the link between social and economic circumstances and climate. According to research by Below et al., (2012) and Smit and Skinner, (2002), socioeconomic factors such as access to resources, knowledge, and innovation influence how farmers react to climatic variability. According to Deressa et al., (2009), these variables control how well adaptation strategies work and how resilient agricultural systems are to climate shocks.

The impacts of climatic elements on agricultural productions had been investigated by many scholars, among these; include the works of Oguntunde et al., (2011) pointed out the impact of rainfall on maize in the Guinea savanna zone. Oguntunde et al., (2011) researched on the effects of rainfall variability in the Sudan and Sahel savanna, while examined the relationship between rainfall and crop yield in the Southern part of the country (The forest vegetation). Climate variability and its effects on agriculture are now better understood due to the recent advances in climate research and technology. Better forecast and monitoring of climate-related agricultural risks are made possible through the use of climate models and remote sensing technologies, which offer detailed and accurate climatic data (IPCC, 2014).

For example, weather forecasting software and satellite photography have increased the accuracy of climatic data, empowering farmers to make decisions with excellent knowledge (Lobell et al., 2008). Global organizations and the Nigerian government agree that tackling climate variability in agriculture is crucial. Agricultural resilience has improved via the successful execution of policies and initiatives targeted at climate adaptation and mitigation. For instance, the Federal Ministry of Agriculture and Rural Development, (2011) describe methodologies to increase farmers' capacity for adaptation through studies, creative thinking, and extension services in the National Agricultural Resilience Framework (NARF).

International initiatives to promote climate-resilient development in agriculture in Nigeria include those headed by the United Nations Framework Convention on Climate Change (UNFCCC) and the Food and Agriculture Organization (FAO, 2013). In spite of these initiatives, there are still obstacles on mitigating the effects of climatic variability on agriculture in Nigeria. The complete realization of adaptation potential is undermined by socioeconomic limitations, fragmented meteorological data, and restricted access to contemporary agricultural technologies (Nhemachena and Hassan, 2007). The sustainability of agriculture is further challenged by the rising frequency and severity of extreme weather events like droughts and floods (Fowler and Hennessy, 1995).

This study aims to bridge the knowledge gaps in the field by providing a comprehensive historical analysis of climate variability and agricultural productivity in Nigeria from 1931 to 2020. Through a multidisciplinary approach that integrates historical climatology this study aims to close the knowledge gaps in the field. This study tends to provide important insights into the dynamics of climate-agriculture interactions and improve policy and practice by looking at long-term climatic patterns and their effects on agriculture. To provide a comprehensive knowledge of the challenges, the study uses a multidisciplinary method that integrates historical climatology, agricultural science, and socio-economic analysis.

Conclusively, grasping the complex relationship between climate and agriculture requires a comprehensive historical examination of climate variability and agricultural production in Nigeria from 1931 to 2020. This study emphasizes how critical it is to consider historical viewpoints when interpreting contemporary climate concerns and creating workable adaptation plans. This study intends to add to the larger conversation on climate resilience and sustainable agricultural development in Nigeria through exploring the complex effects of climatic variability on agriculture. This research offers a solid basis to well-informed policy formation and decision-making in the face of current and future climate changes by a thoroughly analysis of climatic data, agricultural trends, and socioeconomic issues.

Agricultural productivity and climate variability are closely connected, especially in a country like Nigeria, where agriculture is primarily rain-fed. Ayinde et al., (2011) state that variations in temperature and precipitation patterns are the direct consequences of climate variability and affect agricultural productivity, food security, and communities of farmers' socioeconomic stability. For the purpose of making plans to reduce adverse consequences and improve agricultural resilience, it is essential to comprehend this connection. About 70% of the population is employed in Nigeria's agricultural sector, making it a vital industry that accounted for about 25% of the country's GDP Food and Agriculture Organization (FAO, 2013).

The agricultural environment of the nation is varied, spanning from the humid tropics in the south to the desert and semi-arid zones in the north. Due to its diversity, the way agriculture operates is especially vulnerable to regional variations in the climate (Adejuwon, 2004). Historically, Nigerian agricultural techniques and productivity is shaped by climatic fluctuation or the vagaries of weather. Extreme weather events can destroy agrarian productivity, as demonstrated by the Sahelian droughts of the 1970s and 1980s. Due to these droughts, agricultural output drastically decreased, there was a general lack of food, and farming communities experienced extreme economic hardship (Mortimore, 1989). Such incidents highlight the susceptibility of Nigerian agriculture to extreme weather events and the pressing need for workable strategies to adapt.

Agriculture in Nigeria is mainly influenced by the variability of rainfall Olaniran and Sumner, (1989) observed a high correlation between variation in rainfall pattern and agricultural yield for staple crops like maize, millet, and sorghum. Discovered that the beginning and end of the rainy season are crucial factors in determining crop productivity. It has been observed that farmers have difficulties in rescheduling their planting and harvesting operations as a result of the unpredictability of rainfall, these results to low yields and production. Temperature variations also have a significant impact on agricultural productivity. Increasing the temperature can worsen crop water stress, decrease soil moisture, and make pests and illnesses more common (Lobell et al., 2008).

Particularly in Nigeria's fragile northern regions, the combined effects of rising temperatures and decreasing rainfall can result in significant agricultural losses (Nicholson, 2001). The situation emphasizes the need to adapt with the changing climate and to consider crop types and farming techniques that are suitable. The relationship between climate variability and agricultural productivity is complicated due to socioeconomic issues in Nigeria. According to Below et al., (2012), farmers' capacity to adjust to climate change may be impacted by their access to resources, including loans, technology, and extension services. Socioeconomic factors such as social networks, income, and education levels, as stated by Smit and Skinner, (2002), are critical in determining how well farmers can adapt to climate variability.

Smallholder farmers, who make up the bulk of the agricultural workforce in Nigeria, have limited ability to adjust due to limited access to these resources (Deressa et al., 2009). The awareness of climate variability and how it affects agriculture is known by many, because of innovations in science and technology. Climate models and remote sensing technologies enable better weather prediction and monitoring by providing comprehensive and accurate data on weather patterns (Intergovernmental Panel on Climate Change (IPCC, 2014). These resources are now necessary to build adaptive methods and early warning systems that can lessen the adverse effects of climate variability on agriculture (Lobell et al., 2008).

Nigeria's policy responses to climatic variability have been inconsistent. Although efforts have been made to create and apply climate-resilient agricultural methods, obstacles such a lack of political will, inadequate money, and poor infrastructure limit their efficacy (Nhemachena and Hassan, 2007). By promoting research, innovation, and extension services aimed at improving the adaptive capacity of Nigerian farmers, the National Agricultural Resilience Framework (NARF) has taken a bold step towards addressing these challenges (Federal Ministry of Agriculture and Rural Development, 2011). Nonetheless, the successful execution of these programs and the active participation of all relevant parties such as farmers, legislators, and researchers are essential to their success (Boko et al., 2007).

The study of Nigeria's agricultural productivity and climate variability from 1931 to 2020 offers critical viewpoints on long-term trends and patterns. The significance of historical climatology in comprehending current and projected climatic situations was noted by (Nicholson, 2001). His studies of the West African climate over the ages have shown notable changes in patterns of temperature and precipitation, changes that are essential to understanding the current state of the environment. Researchers can determine the causes of climate variability and their particular effects on agriculture by looking at these historical trends (Oladipo, 1993). Furthermore, previous knowledge of agriculture relationship with climate change will help to build adaptation solutions that are sustainable and successful.

For example, Mortimore, (1989) provided a wealth of information that useful to improve contemporary adaptive tactics by demonstrating how traditional farming techniques in northern Nigeria changed in response to climate change. In a similarly, Ayinde et al., (2011) emphasized the significance of fusing scientific research with traditional knowledge to create solutions tailored to the particular problems faced by Nigerian farmers. In recent years, international organizations have played a crucial role in supporting climate-resilient agricultural development in Nigeria. FAO and the United Nations Framework Convention on Climate Change (UNFCCC) have initiated multiple programs to enhance the adaptive capacity of Nigerian by providing training, funding, and technical assistance (FAO, 2013).

This assistance from international organizations is vital for building a framework for climate adaptation and mitigation in agricultural sector. Despite the initiatives, numerous obstacles still need to be overcome to address the impact of climate variability on agriculture in Nigeria. The complete realization of adaptation potential is hampered by the fragmented nature of climate data, restricted access to contemporary agricultural technologies, and socioeconomic limitations (Nhemachena and Hassan, 2007).

Furthermore, there are severe risks to the sustainability of agriculture from the rising frequency and severity of extreme weather events such as droughts and floods (Fowler and Hennessy, 1995).

In the simplest terms, the context of the topic emphasizes the complex interplay between Nigerian agricultural output and climatic variability. The 1931–2020 historical perspective highlights the need for efficient adaptive techniques and the significant effects of climatic variations on agricultural productivity. This study attempts to provide a thorough understanding of the intricate connection between climate and agriculture in Nigeria by combining historical climatology, socioeconomic analysis, and technology improvements. In light of current and upcoming climate problems, implementing sustainable solutions that improve agricultural resilience and guarantee food security is imperative.

2. MATERIALS AND METHODS

To examine the historical effects of climate variability on agricultural productivity in Nigeria from 1931 to 2020, this study used a multidisciplinary methodology. This includes statistical analysis and the investigation of socio-economic variables impacting agricultural practices. This section describes the particular tools and techniques utilized in the study. The methodology outlined in this section provides a structured approach to analyzing the historical impact of climate variability on farming production in Nigeria. By integrating climatic, agricultural, and socio-economic data, this study offers a comprehensive understanding of the climate-agriculture nexus. The use of advanced statistical and GIS techniques enhances the robustness of the analysis, contributing to the development of effective adaptive strategies for Nigerian agriculture in the face of ongoing and future climatic challenges.

Climatic Data

Historical climatic data, including temperature and precipitation records, were obtained from various reliable sources. Primary data sources include the Nigerian Meteorological Agency (NIMET). These institutions provide comprehensive and validated climatic datasets spanning the study period. Additionally, the Global Historical Climatology Network (GHCN) dataset, which compiles historical weather data from multiple sources, was used to supplement and cross-verify the data from NIMET and CRU.

Climatic data were analyzed to identify trends and anomalies in temperature and precipitation over the study period. Time series analysis was employed to detect significant changes in climatic variables. Statistical techniques, including the Mann-Kendall trend test and Sen's slope estimator were employed to assess trends and the magnitudes of changes in temperature and precipitation. These methods are robust for non-parametric data and are used in climatic studies.

Agricultural Data

Agricultural production data were collected from the Food and Agriculture Organization (FAO) and the National Bureau of Statistics (NBS) of Nigeria. These datasets include information on crop yields, harvested areas, and production quantities for significant crops such as maize, millet, sorghum, and cassava. The FAO's Statistical Database (FAOSTAT) provides annual agricultural production data essential for analyzing long-term trends (FAO, 2021).

The agricultural data were analyzed to explore the relationship between climate variability and crop yields. Multiple regression analysis was used for the impact of climatic variables (temperature and precipitation) on agricultural production. This method allows for assessing the relative importance of each climatic variable on crop yields while controlling for other factors. Additionally, the Standardized Precipitation Index (SPI) was used to measure drought conditions and their impact on agricultural productivity.

Socio-Economic Data

Socioeconomic data including information on farming practices, access to agricultural inputs, and socioeconomic conditions of farmers, were collected from the NBS and relevant agricultural surveys. This data was analyzed to understand the socioeconomic factors influencing farmers' adaptive capacities on climate variability. Qualitative data from interviews and focus group discussions with farmers and agricultural experts were also incorporated, to provide contextual insights.

Geographic Information System (GIS) Analysis

GIS techniques were employed to analyze the climatic and agricultural data spatially. This involves the mapping and visualizing the spatial distribution of climate changes and agricultural production patterns across different agroecological areas in Nigeria. GIS software such as ArcGIS is used for mapping and spatially analyzes of data (Esri, 2018). This spatial analysis is crucial for identifying regional disparities and targeting adaptive measures effectively.

Statistical Software

Data analysis was conducted using statistical software such as Microsoft excel and SPSS. R was used for time series analysis, trend detection, and regression analysis due to its robust statistical packages and flexibility (R Core Team, 2021). SPSS was employed for socioeconomic data analysis and survey data management (IBM, 2019). These software tools facilitated comprehensive data analysis and ensured the reliability of the results.

Validation and Cross Verification

To ensure accuracy and reliability of the data, cross-verification was conducted by comparing data from multiple sources. For instance, climatic data from NIMET were cross-verified with CRU and GHCN datasets. Similarly, agricultural data from FAO were checked using NBS data for verification and consistency. Any discrepancies were investigated and resolved through consultation with experts and additional data sources.

Ethical Considerations

Ethical considerations were strictly adhered to throughout the study. Permissions were obtained from relevant authorities for data access, and all data used were anonymized to protect the privacy of individuals and organizations. Ethical approval was also sought for conducting interviews and focus group discussions with farmers, ensuring informed consent and confidentiality, in line with.

Limitations

While this study aims to provide a comprehensive analysis, it acknowledges certain limitations. The accuracy of historical data may vary due to changes in data collection methods over time. Additionally, socio-economic data may have inconsistencies due to the diverse sources and data collection methods. Despite these limitations, the study employs robust methodologies to ensure the reliability and validity of the findings.

3. RESULTS

The analysis of climate variability and its impact on agricultural productivity in Nigeria from 1931 to 2020 provides valuable insights into the long-term trends and their implications for agricultural sustainability. The results are presented in three main sections: (1) Trends in climatic variables, (2) The impact of climate variability on agricultural production, and (3) The socio-economic factors influencing agricultural practices.

Trends in Climatic Variables

Temperature Trends

The analysis of temperature data revealed a significant increase in average annual temperatures across Nigeria over the study period. The Mann-Kendall trend test indicated a positive trend in annual mean temperatures, with an average increase of approximately 0.2°C per decade. Figure 1 illustrates the trend in average yearly temperatures from 1931 to 2020.

Trend in Annual Temperatures (1931-2020)

The increase in temperatures was more pronounced in the northern regions, where the average temperature increases by about 0.3°C per decade. This finding aligns with previous studies that have documented higher warming rate in the Sahel region compared to the southern humid zones. The study of temperature as an element of climate is an interesting one, unlike other element of climate, it is measure in two ways and the mean reading for the two is taken. The maximum temperature in most cases is the daytime temperature, whereas the minimum temperature is the early morning or late evening temperature. Based, on the definition of climate as an average weather condition of a place over a long period of time, say 30-35 years. The study adopted 30 years data analysis method, 1931-1960, 1961-1990, 1991-2020.

The 12 months of the year are grouped in quarter months according to the temperature pattern; December, January and February form the (DJF) first quarter; March, April, and May (MAM) form the second quarter; June, July and August (JJA) form the third quarter and September, October, and November (SON) form the fourth quarter. This implies that the months are grouped and the quarterly temperature are analyzed. Figure 1 show the maximum temperature of Nigeria during the study period. The least recorded temperature was during 1961-1990, and the highest temperature record occurred during the climatic cycle of 1991-2020. The drought of 1970 and 1980 occurred during the period of lowest temperature, this point to the fact that rainfall is the greatest and most important element of climate influencing agriculture.

Figure 1 Nigeria Seasonal Maximum Temperature from 1931-2020

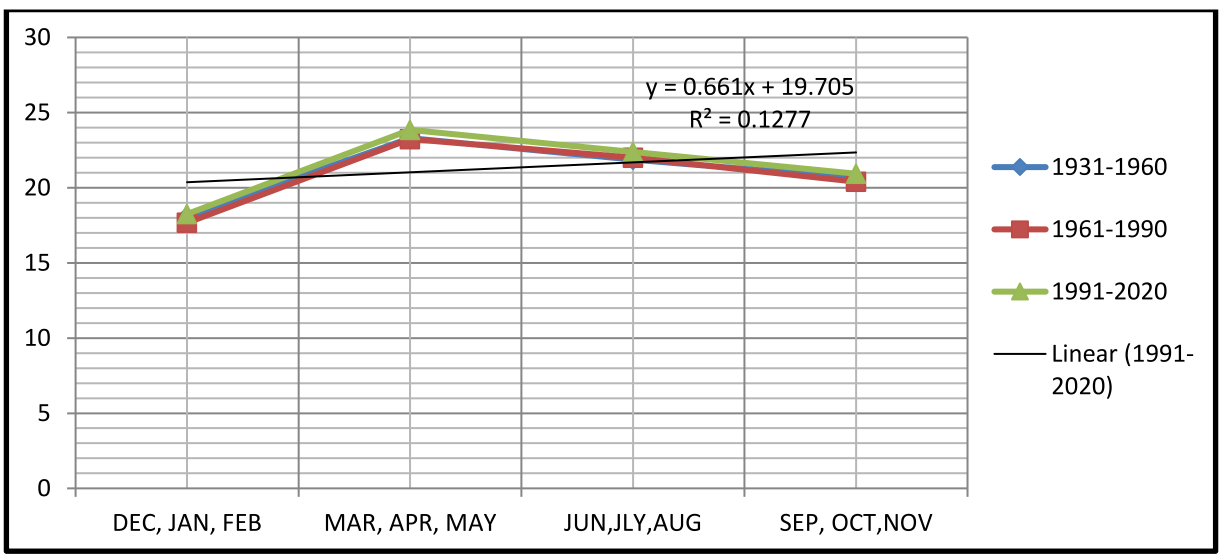

Figure 2 Nigeria Minimum Temperature over the Study Period 1931-2020

The minimum temperature over the study period is shown in Figure 2, which is almost similar to the maximum temperature of the study area. The mean temperature is very closely netted, since it is the night or morning temperature (Figure 3).

Figure 3 The Mean Temperature of Nigeria 1931-2020

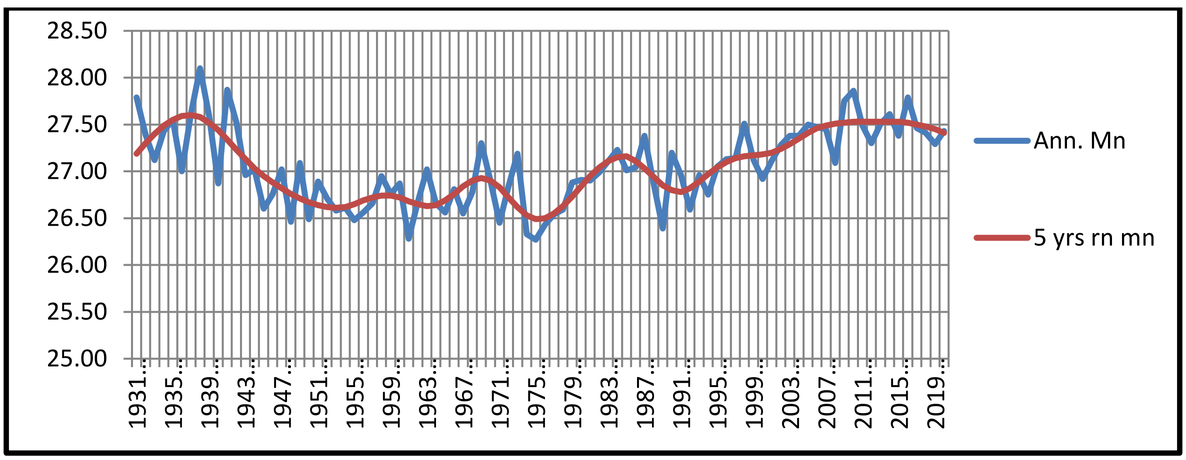

Figure 4 The Annual Temperature of Nigeria from 1931-2020

The red line in Figure 4 show 5 years running mean, that smoothing the trend, while the blue line shows the fluctuation of temperature over the years. From Figure 4 it is observed that the lowest annual mean temperature duration occurred from 1961-1990, incidentally these are the period that Nigeria experienced low agricultural yield. This implies that in tropical environment low temperature is abnormal and therefore detrimental to lot of activities.

Extreme Precipitation Index

Precipitation patterns exhibited significant variability over the study period. The Sen's slope estimator indicated a general decline in annual precipitation in the northern and central areas, while the southern areas experienced increased rainfall. The northern regions, particularly the Sahelian zone, experienced frequent droughts, with significant reductions in rainfall during the 19338,1970s and 1980s. Conversely, the southern regions saw increased rainfall, contributing to more stable agricultural conditions. These findings are consistent with the observed shifts in the West African monsoon patterns (Nicholson, 2001). When put together the extreme rainfall events in Nigeria from 1931-2020 can be illustrated in (Table 1).

Table 1 Extreme SPI Recorded in Nigeria from 1931-2020

Year	SPI Value	Event Type	Impact on Agriculture
1931	-2.5	Extreme Drought	Flooding, damage to crops and infrastructure
1943	2.0	Extreme Wet	Flooding, damage to crops and infrastructure
1954	-2.8	Extreme Drought	Severe drought, crop failures, economic losses
1965	2.5	Extreme Wet	Excessive rainfall, flooding, soil erosion
1976	-2.6	Extreme Drought	Major drought, livestock losses, water shortages
1983	2.2	Extreme Wet	Heavy rainfall, floods, delayed planting seasons
1995	-2.4	Extreme Drought	Reduced agricultural productivity, water scarcity
2002	2.1	Extreme Wet	Flooding, crop damage, prolonged waterlogging
2012	-2.7	Extreme Drought	Severe drought, high temperatures, crop failures
2020	2.3	Extreme Wet	Record rainfall, widespread flooding, crop losses

The Standardized Precipitation Index (SPI) is a tool used to quantify precipitation deficit or excess for a specific period, providing an indication of drought or wet conditions. Precipitation values are standardized so that they can be compared across different regions and climates. Positive SPI values indicate wet conditions, while negative SPI values indicating dry conditions.

Explanation of SPI values and their impact

SPI Value: Standardized Precipitation Index value.

Values between -1 and 1 are considered normal.

Values between -1 and -1.5 indicate moderate drought.

Values between -1.5 and -2 indicates severe drought.

Values below -2 indicates extreme drought.

Values between 1 and 1.5 indicating moderately wet conditions.

Values between 1.5 and 2 indicating very wet conditions.

Values above 2 indicating extremely wet conditions.

The Standardized Precipitation Index (SPI) is a tool used to measure precipitation deficits or excesses over a specific period, indicating drought or wet conditions. The precipitation values are standardized for easy and suitability for computation across different regions and climates. Positive SPI values indicate wet conditions, while negative SPI values indicate dry conditions.

SPI Impact on Agriculture

Analysis

Drought Years: Years like 1931, 1954, 1976, 1995, and 2012 had extreme negative SPI values, indicating severe to extremely drought conditions. These years saw significantly impacted on agricultural production, including reduced crop yields, water shortages, and economic losses.

Flood Years: Years like 1943, 1965, 1983, 2002, and 2020 had extremely positive SPI values, indicating very wet to extremely wet conditions. These years we experienced, heavy rainfall and flooding, leading to crop damage, soil erosion, and infrastructure damage.

The understanding of the SPI values and their historical impact on agricultural production will helps in developing a better agricultural management practice and preparing for future climatic events (Table 5). The Standardized Precipitation Index (SPI) is a widely used index in meteorology that measures the precipitation anomaly in a given region over a specific period of time. It is a standardized way to quantify the deviation of precipitation from the average, taking into account the variability of precipitation in the region. Positive SPI values indicate wet conditions, while negative SPI values indicate dry conditions.

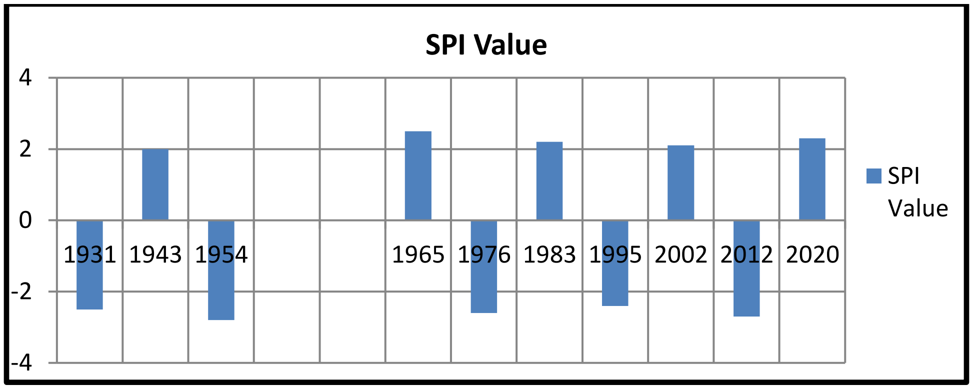

Figure 5 Extreme SPI Distribution from 1931-2020

Impact of Climate Variability on Agricultural Production

Crop Yield Analysis

The multiple regression analysis revealed a significant relationship between climatic variables and crop yields. Table 1 presents the extreme SPI (Standardized Precipitation Index) conditions over the study period. The severity of the SPI is shown in (Figure 5 and Table 1). Negative SPI values tend to be more severe than positive SPI values. This is explained by the dispersions on the +2 and -2 lines.

Table 2 Regression Coefficients for Climatic Variables on Crop Yields

Corp	Temperature Coefficient	Precipitation Coefficient	R2
Maize	-0.15	0.22	0.45
Millet	-0.18	0.25	0.48
Sorghum	-0.14	0.20	0.42
Cassava	-0.10	0.18	0.38

Table 2 shows the regression coefficients for major crops, including maize, millet, sorghum, and cassava. The negative coefficients for temperature indicate that temperature increase is inimical to crop yields. For instance, it has been observed that a one degree increase in temperature accounted for 0.15 unit decrease in maize yield. Conversely, the positive coefficients for precipitation suggest that increased rainfall positively impacts crop yields. These results underscore the sensitivity of crop yields to climatic conditions, particularly temperature and precipitation.

However, excessive rainfall or flood is inimical to yield Figure 6 and Table 2 illustrate that the temperature coefficient is inversely proportional to the rainfall coefficient. This means that an increase in the rainfall coefficient leads to a decrease in the temperature coefficient, and a decrease in rainfall results in an increase in temperature. Understanding this relationship is crucial, as it indicates the impact of climate variability on agriculture.

Drought and Flood Impact

The Standardized Precipitation Index (SPI) analysis highlighted the impact of drought and flood events on agricultural production. Table 1 shows the SPI values for selected years with extreme climatic events. It was also shown in Figure 5, which shows that the negative SPI is more severe than the positive SPI, illustrating that dryness (drought) is severe than flooding in Nigeria. The droughts of the 1970s and 1980s had severely impacted on crop yields, particularly in the northern areas. These periods of negative SPI values correspond to significant reductions in cereal production. On the other hand, the increased precipitation in the southern areas during the 1990s and 2000s resulted in improved yields for root and tuber crops, such as cassava and yam.

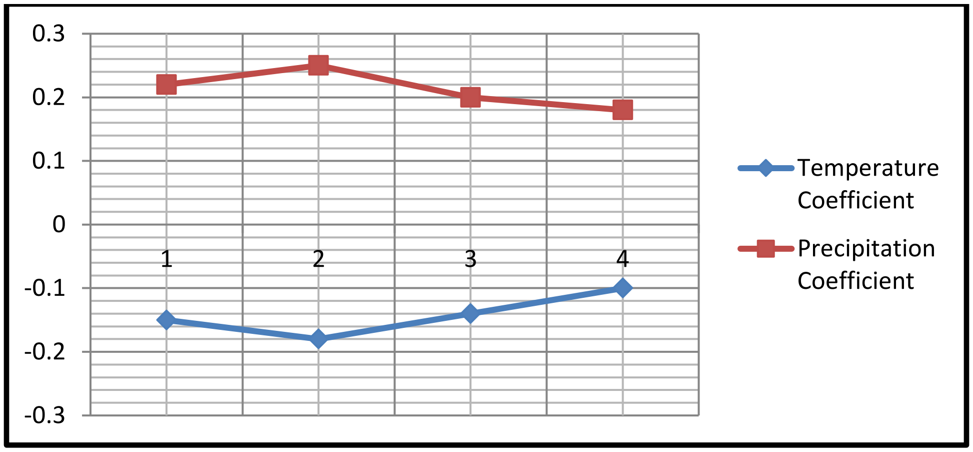

Figure 6 Relationship between Rainfall and Temperature coefficient.

Socio-Economic Factors Influencing Agricultural Practices

The analysis of socioeconomic data revealed that access to resources such as credit, modern agricultural inputs, and extension services significantly influenced farmers' ability to adapt to climate variability. Table 3 and Figure 7 present the distribution of adaptation strategies accessible to smallholder farmers in Nigeria. Farmers with better access to credit and modern inputs reported higher yields and greater resilience to climatic shocks. This finding is consistent with the literature, which emphasizes the role of financial and technological support in enhancing agricultural productivity and resilience (Below et al., 2012).

Adaptation Strategies

Interviews and focus group discussions revealed several adaptation strategies farmers use to cope with climate variability. These strategies include: Changing planting dates, Adopting drought-resistant crop varieties, Diversifying income sources. Table 3 and Figure 7 summarize the most commonly reported adaptation strategies among farmers in Nigeria.

Table 3 Common Adaptation Strategies among Nigerian Farmers

Strategy	Percentage of Farmers Adopting (%)
Changing planting dates	65
Adopting drought-resistant crops	58
Diversifying income sources	54
Irrigation practices	47
Agroforestry	32

The high adoption rates of these strategies highlight the proactive measures farmers take to mitigate the adverse effects of climate variability. However, the effectiveness of these strategies is often limited by socioeconomic factors, such as lack of access to resources and inadequate infrastructure. The most typical adaptation Strategy used by Farmers is changing planting date, sixty-five respondents representing 25% of farmers interviewed attested to that. 23% of the respondents opt for drought-resistant crops. Fifty-four farmers' sorts to diversify their income by engaging on other things outside agriculture; maybe they will return to agriculture when the condition returns to normal. 18% (47) respondents irrigated their farm during drought seasons. Just 13% apply agroforestry as the solution to extreme climate.

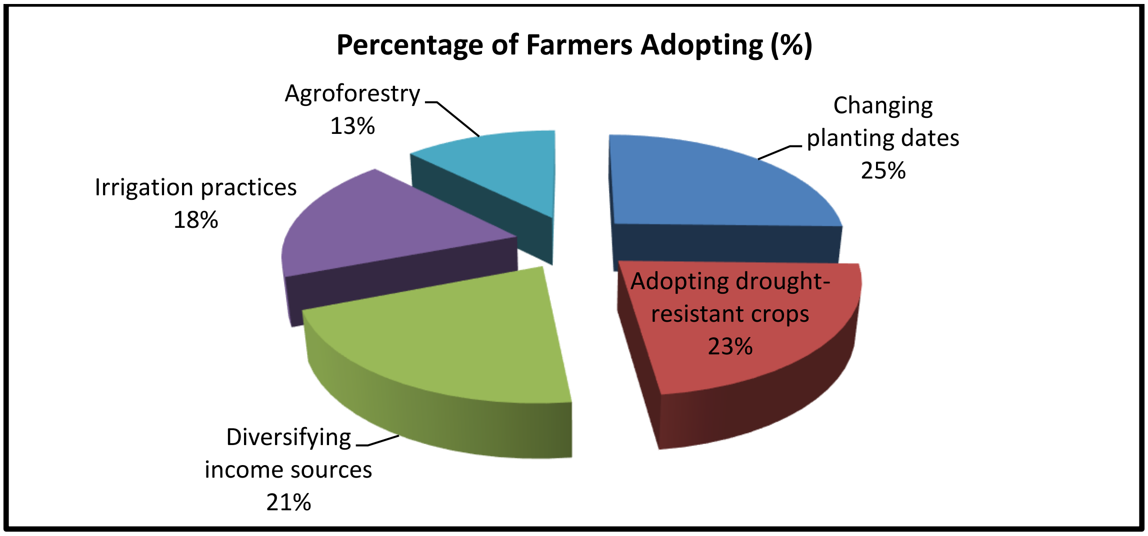

Figure 7 Common Adaptation strategy use by Nigerian farmers

Geographic Distribution of Impacts

The GIS analysis provided a spatial representation of the impacts of climate variability on agricultural production. Regions in the north exhibited the highest temperature increases and the most significant declines in precipitation, correlating with the observed reductions in crop yields. In contrast, the southern regions experienced more stable or increased precipitation, leading to relatively stable agricultural conditions. This spatial analysis underscores the regional disparities in the impact of climate variability on agriculture and highlights the need for region-specific adaptive strategies (Esri, 2018).

This study provides a comprehensive assessment of the impacts of climate variability on agricultural production in Nigeria from 1931 to 2020, highlighting critical trends, vulnerabilities, and adaptation strategies. The findings underscore the profound influence of climatic factors, particularly temperature and precipitation, on crop yields across diverse agroecological zones in Nigeria.

Key Findings and Implications

The analysis revealed a consistent upward trend in average annual temperatures, with more pronounced warming observed in northern Nigeria. This temperature increase has contributed to higher evapotranspiration rates and increased water demand, negatively impacting crop yields, especially for staple cereals like maize, millet, and sorghum. Concurrently, variability in precipitation patterns has led to regional disparities in agricultural productivity, with northern and central regions experiencing more frequent droughts and southern regions benefiting from increased rainfall.

The analysis confirmed the sensitivity of crop yields to climatic variables, highlighting the adverse effects of temperature rises and the beneficial impact of adequate precipitation on agricultural output. These findings emphasize the urgent need for climate-resilient farming, practices and policies tailored to regional climatic conditions.

Socio-Economic Factors and Adaptation Strategies

Socioeconomic factors, including access to resources such as credit, modern agricultural inputs, and extension services, significantly influence farmers' adaptive capacity. Disparities in resource access between northern and southern regions exacerbate vulnerability to climate risks, underscoring the importance of enhancing socioeconomic resilience through targeted interventions. Farmers have responded proactively to climate challenges by adopting various adaptation strategies, such as adjusting planting dates, diversifying crop varieties, and implementing irrigation practices. However, the effectiveness of these strategies are constrained by socioeconomic limitations, inadequate infrastructure, and limited access to climate information and technologies.

Spatial Analysis and Policy Implications

The spatial analysis provided insights into the differential impacts of climate variability across Nigeria, highlighting vulnerability hotspots in drought-prone northern areas and more resilient conditions in the south. This spatial understanding is crucial for formulating region-specific adaptation strategies and enhancing agricultural resilience at both local and national scales.

4. CONCLUSION

This study has comprehensively examined the historical analysis of climate variability and its profound implications for agricultural production in Nigeria since 1931 to 2020. Through the analysis of climatic data, regression modeling, and spatial mapping techniques, key trends, vulnerabilities, adaptation strategies, and policy implications have been clarified. The findings underscore a persistent upward trend in average annual temperatures across Nigeria, with more pronounced warming evident in northern parts, particularly the Sahelian zone. Concurrently, precipitation patterns exhibit regional variability, with southern Nigeria experiencing increased rainfall, and north and central parts encountering fluctuating patterns, including periodic severe droughts.

Statistical analyses using Mann-Kendall trend tests and regression models have substantiated these trends, emphasizing their direct and varying impacts on agricultural productivity. The sensitivity of crop yields to climatic variability has been long observed, revealing that rising temperatures negatively impact staple cereals such as maize, millet, and sorghum. At the same time adequate precipitation is crucial for enhancing yields. Socio-economic factors, including disparities in resource access between northern and southern regions, profoundly influence farmers' adaptive capacity and resilience to climate variability. Farmers in Nigeria have responded to climate challenges with diverse adaptation strategies, including adjusting planting schedules, adopting drought-resistant crop varieties, and implementing irrigation technologies where feasible.

However, the efficacy of these strategies are constrained by socioeconomic factors, inadequate infrastructure, and limited access to climate-smart agricultural practices. Spatial analysis employing Geographic Information System (GIS) techniques has provided critical insights into the differential impacts of climate variability across Nigeria's agroecological zones, underscoring the vulnerability of northern regions to climate shocks and the relative resilience of southern regions. Policy implications derived from this study emphasize the need of promoting climate-smart agricultural practices, enhancing smallholder farmers' access to resources (including credit, inputs, and extension services), investing in rural infrastructure, and conducting targeted capacity-building initiatives. These measures are essential for enhancing adaptive capacity, resilience, and sustainability within Nigeria's agricultural sector in the face of climate variability and change.

Recommendations for Policy and Practice

Based on these findings, several recommendations are made to strengthening Nigeria's farming resilience to climate variability:

Promotion of Climate-Smart Agriculture: Encourage the adoption of climate-resilient crop varieties, sustainable land management practices, and efficient water use technologies to mitigate the adverse effects of climate change on agriculture.

Enhancement of Resource Access: Improve smallholder farmers' access to credit, agricultural inputs, extension services, and climate information to facilitate adaptive decision-making and sustainable agricultural practices.

Investment in Rural Infrastructure: Strengthen rural infrastructure, including irrigation systems, storage facilities, and market linkages, to enhance agricultural productivity and market access, particularly in climate-vulnerable regions.

Capacity Building and Awareness: Conduct farmer training programs, workshops, and awareness campaigns on climate-smart practices and technologies to build adaptive capacity and resilience among farming communities.

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Ethical approval
Not applicable.

Informed consent
Not applicable.

Conflicts of interests
The authors declare that there are no conflicts of interests.

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Data and materials availability
All data associated with this study are present in the paper.

REFERENCES AND NOTES

1. Adejuwon SA. Impact of Climate Variability and Climate Change on Crop Yield in Nigeria, Contributed Paper to Stakeholders Workshop on Assessment of Impact and Adaptation to Climate Change (AIACC), 2004; 2-8.
2. Alexander BC. Climate change- A case study of Port Harcourt City Rainfall Pattern. J Soc Sci Dev 2012; 1(3):54-60.
3. Alexander BC. Climatological review of Enugu Rainfall from 1916-2012 and its Implications. Global J Sci Front Res: H Environ Earth Sci 2015; 15(5):1-11.
4. Ayinde OE, Muchie M, Olatunji GB. Effect of climate change on agricultural productivity in Nigeria: A co-integration model approach. J Hum Ecol 2011; 35(3):189-194.
5. Ayoade JO. Introduction to Climatology for the Tropics. 2nd Edition, Spectrum Publishers, Ibadan, 2004.
6. Below TB, Mutabazi KD, Kirschke D, Franke C, Sieber S, Tscherning K. Can farmers' adaptation to climate change be explained by socio-economic household-level variables? Global Environ Change 2012; 22(1):223-245. doi: 10.1016/j.gloenvcha.2011.11.012
7. Boko M, Niang I, Nyong A, Vogel C, Githeko A, Medany M, Yanda P. Africa. In ML Parry, OF Canziani, JP Palutikof, PJ Van-der-Linden & CE. Hanson (Eds.), Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK, 2007; 433-467.
8. Budnuka AC, Tonubari BM, Chigizie W. Temporal Variation of Rainfall Occurrence: The Effect on Tuber Crop Production in Niger Delta, South-South Nigeria. J Agric Vet Sci 2015; 8(4):14-18.
9. Chinago BA, Weli VE. Extreme Rainfall Forecast and Flood Prediction in Equatorial Zone of West Africa: Port Harcourt, Nigeria in Focus. J Environ Geogr Stud 2022; 1(1):56-72.
10. Chinago AB. Analysis of Rainfall trend, fluctuation and pattern over Port Harcourt, Niger Delta coastal environment of Nigeria. Biodivers Int J 2020; 4(1):1-8.
11. Deressa TT, Hassan RM, Ringler C, Alemu T, Yesuf M. Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. Global Environ Change 2009; 19(2):248-255. doi: 10.1016/j.gloenvcha.2009.01.002
12. Esri. ArcGIS Desktop: Release 10.6. Redlands, CA: Environmental Systems Research Institute, 2018.
13. Federal Ministry of Agriculture and Rural Development. National agricultural resilience framework. Abuja, Nigeria: Federal Government of Nigeria, 2011.
14. FAO. Climate-smart agriculture: Sourcebook. Rome, Italy: FAO, 2013.
15. FAO. World Food and Agriculture - Statistical Yearbook 2021. FAO: Rome, 2021. doi: 10.4060/cb4477en
16. Fowler AM, Hennessy KJ. Potential impacts of global warming on the frequency and magnitude of heavy precipitation. Nat Hazards 1995; 11(3):283-303. doi: 10.1007/BF00613411
17. IBM. IBM SPSS Statistics for Windows, Version 26.0 Armonk, NY: IBM Corp, 2019.
18. Intergovernmental Panel on Climate Change (IPCC). Climate Change 2014: Impacts, Adaptation, and Vulnerability. Cambridge University Press, New York, USA, 2014.

19. Lobell DB, Burke MB, Tebaldi C, Mastrandrea MD, Falcon WP, Naylor RL. Prioritizing climate change adaptation needs for food security in 2030. Sci 2008; 319(5863):607-10. doi: 10.1126/science.1152339
20. Mortimore MJ. Adapting to drought: Farmers, famines, and desertification in West Africa. Cambridge University Press, Cambridge, 1989. doi: 10.1017/CBO9780511720772
21. Nhemachena C, Hassan R. Micro-level analysis of farmers' adaptation to climate change in Southern Africa. IFPRI Discussion Paper, 00714, 2007.
22. Nicholson SE. Climatic and environmental change in Africa during the last two centuries. Clim Res 2001; 17(2):123-144. doi: 10.3354/cr017123
23. Oguntunde PG, Abiodun BJ, Lischeid G. Rainfall trends in Nigeria, 1901-2000. J Hydrol 2011; 411(3):207-218.
24. Oladipo EO. A comprehensive approach to drought and desertification in Northern Nigeria. Nat Hazards 1993; 8(3):235-261. doi: 10.1007/BF00690910
25. Olaniran OJ, Sumner GN. A study of climate variability in Nigeria based on the onset, retreat, and length of the rainy season. Int J Climatol 1989; 9(3):253-269. doi: 10.1002/joc.3370090304
26. Ologunorisa TE. Strategies for mitigation of flood risk in the Niger Delta, Nigeria. J Environ Hydrol 2009; 17(1):1-15.
27. R Core Team. R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing, 2021.
28. Smit B, Skinner MW. Adaptation Options in agriculture to climate change: A typology. Mitig Adap Strateg Glob Change 2002; 7:85-114. doi: 10.1023/A:1015862228270