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Historical Analysis of Climate Variability and Agricultural Production in Nigeria (1931-2020)

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Abstract

This study investigates the historical dynamics of climate variability and its impacts on agricultural production in Nigeria from 1931 to 2020. Utilizing a robust analytical framework that integrates climatic data analysis, statistical modelling, and geographic information system (GIS) techniques, the research explores trends in temperature and precipitation across different agro-ecological zones. Key findings reveal a consistent upward trend in average annual temperatures, with more pronounced warming observed in northern Nigeria, notably the Sahelian zone. Concurrently, precipitation patterns exhibit regional disparities, characterized by increased rainfall in southern regions and variable patterns in the north, including periods of severe droughts during the 1970s and 1980s. Statistical analyses employing Mann-Kendall trend tests and regression models confirm significant temperature increases and varying precipitation trends, underscoring their direct impacts on agricultural productivity. The study highlights the sensitivity of crop yields to climatic factors, demonstrating that rising temperatures adversely affect staple crops such as maize, millet, and sorghum, while adequate precipitation plays a critical role in enhancing yields. Socio-economic factors, including disparities in resource access between northern and southern regions, influence farmers' adaptive capacity and resilience to climate variability. Adaptation strategies adopted by Nigerian farmers, such as adjusted planting schedules, crop diversification, and irrigation practices, are explored within the context of socio-economic constraints and infrastructural limitations. Spatial analysis using GIS provides insights into the differential impacts of climate variability across Nigeria, emphasizing the vulnerability of northern regions to climate shocks compared to the relative resilience of southern regions. Policy implications underscore the urgency of promoting climate-resilient agricultural practices, improving resource access, enhancing rural infrastructure, and implementing targeted capacity-building initiatives. These measures are essential for enhancing adaptive capacity, resilience, and sustainable agricultural development amidst on going climate variability and change in Nigeria.

Keywords: climate variability, agricultural production, Nigeria, temperature trends, precipitation patterns, adaptation strategies, socio-economic factors

Introduction

The substantial effects of climate variability on food security, economic stability, and social stability have made it a central focus of agricultural study for many years. Ayinde, Muchie, and Olatunji (2011) state that Nigeria is a country that depends mostly on agriculture, so she faces major development and sustainability challenges due to the interaction between climate change and productivity in the agricultural sector. Between 1931 and 2020 — a period characterized by significant climatic fluctuations and agricultural transformations — this study attempts to perform a thorough historical examination of climate variability and its consequences on agricultural productivity in Nigeria.

Nigeria's climate-agriculture relationship is intricate and multidimensional. Because most of Nigeria's agriculture is rain-fed, it is highly susceptible to 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 agro-ecological 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 way of lives than the tropics. Rainfall does not only influence the agricultural sector, but the things people do and when they do it. Climate imposes cost on man, but also bestows benefits. For instance, storms and floods causes damage to crops and sometimes loss of life, but the day to day variations contributes to the rich variety of flora and fauna, which add so much to the quality of lives (Alexander, 2015; Chinago, 2020; Hardy, 2004).

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 adverse impacts on agriculture (Boko et al., 2007).

Long-term trends and patterns can be understood through the analysis of historical climate data. 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 were observed in the West African climate, and these findings are essential for understanding the current state of the climate. These historical viewpoints are essential for creating adaptive techniques that lessen negative effects on agriculture (Boko et al., 2007).

Nigerian agriculture has been influenced 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 susceptible Nigerian agriculture is to climate extremes and the necessity of effective adaptation strategies (Adams, 1986). In fact, it is believed that agriculture is a gamble on the vagaries of climate, because unlike in the temperate region, the tropical people agriculture calendar is determined by onset of rainfall, therefore seasonal rainfall dictate not only the planting period but also the harvesting season (Alexander, 2012; Alexander et al., 2015).

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. (2010) 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.

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 by 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 greater knowledge (Lobell et al., 2008).

Global organizations and the Nigerian government agree that tackling climate variability in agriculture is crucial. Agricultural resilience has been 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) (FAO, 2013; UNFCCC, 2015).

In spite of these initiatives, there are still obstacles in the way of properly mitigating the effects of climatic variability on Nigerian agriculture. The complete realization of adaptation potential is impeded by socioeconomic limitations, fragmented meteorological data, and restricted access to contemporary agricultural technologies (Nhemachena & Hassan, 2007). The sustainability of agriculture is further jeopardized by the rising frequency and severity of extreme weather events like droughts and floods (Fowler & Hennessy, 1995).

By offering a thorough historical analysis of climate variability and agricultural productivity in Nigeria from 1931 to 2020, 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 at hand, 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 spanning 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 by exploring the complex effects of climatic variability on agriculture. This research offers a strong basis for well-informed policy formation and decision-making in the face of current and future climate changes by a thorough analysis of climatic data, agricultural trends, and socioeconomic issues.

Agricultural productivity and climate variability are closely related, especially with areas like Nigeria where agriculture is primarily rain-fed. Ayinde, Muchie, and Olatunji (2011) state that variations in temperature and precipitation patterns are the direct consequences of climate variability and have an effect on agricultural productivity, food security, and communities of farmers' socioeconomic stability. For the purpose of creating 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 makes 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 of its diversity, the way agriculture operates is especially vulnerable to regional variations in the climate (Adejuwon, 2004).

In the past, Nigerian agricultural techniques and results have been significantly shaped by climatic fluctuation. Extreme weather events have the ability to completely destroy agricultural 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 (Adams, 1986).

Nigeria's agricultural productivity is mostly influenced by the variability of rainfall. Research indicates a high correlation between changes in agricultural yields and variations in rainfall patterns (Olaniran & Sumner, 1989). In the case of staple crops like maize, millet, and sorghum, Adejuwon (2005) discovered that the beginning and end of the rainy season are important factors in determining crop productivity. Farmers have to overcome difficulties in scheduling their planting and harvesting operations in areas with unpredictability of rainfall, which results in yields that are below ideal.

Variations in temperature also have a major 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 already fragile northern regions, the combined effects of rising temperatures and decreasing rainfall can result in significant agricultural losses (Nicholson, 2001). This emphasizes the necessity of crop types and farming techniques that are temperature-resistant.

The relationship between climate variability and agricultural productivity is further complicated by socioeconomic issues. According to Below et al. (2010), 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 are able to adapt to climate variability. Smallholder farmers, who make up the bulk of the agricultural workforce in Nigeria, have limited ability to adapt due to limited access to these resources (Deressa et al., 2009).

The awareness of climatic variability and how it affects agriculture has grown because to innovations in technology. Better weather prediction and monitoring are made possible by climate models and remote sensing technologies, which offer comprehensive and precise 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 negative 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 & Hassan, 2007). By encouraging research, innovation, and extension services targeted at improving the adaptive capacity of Nigerian farmers, the National Agricultural Resilience Framework (NARF) represents a significant step towards addressing these challenges (Federal Ministry of Agriculture and Rural Development, 2011). Nonetheless, 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 important completely novel viewpoints on long-term trends and patterns. The significance of historical climatology in comprehending current and projected climatic situations was underlined 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 climate. Researchers can determine the causes of climate variability and their particular effects on agriculture by looking at these historical trends (Oladipo, 1993).

Furthermore, knowledge of past interactions between agriculture and climate change might help build adaptation solutions that are sustainable and successful. For example, Mortimore (1989) provided a wealth of information that can be used to improve contemporary adaptive tactics by demonstrating how traditional farming techniques in northern Nigeria changed in response to climate changes. In a similar vein, 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. The FAO and the United Nations Framework Convention on Climate Change (UNFCCC) have launched several initiatives aimed at improving the adaptive capacity of Nigerian farmers through training, funding, and technical assistance (FAO, 2013; UNFCCC, 2015). These efforts are essential for building a robust framework for climate adaptation and mitigation in the agricultural sector.

Even with these initiatives, there are still a lot of obstacles to overcome in order to address how climate variability affects 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 & Hassan, 2007). Furthermore, there are serious risks to the sustainability of agriculture from the rising frequency and severity of extreme weather events such droughts and floods (Fowler & 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 of 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.

Materials and Methods

To examine the historical effects of climate variability on agricultural productivity in Nigeria from 1931 to 2020, this study uses a multidisciplinary methodology. In addition to statistical analysis and the investigation of socio-economic variables impacting agricultural practices, the methodology also includes the gathering and analysis of historical climate and agricultural data. This section provides a description of 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 agricultural 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.

Material and Methods

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 (Ilesanmi, Adewale, & Bolarinwa, 2020). 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 (Mann et al., 2022).

The 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 such as the Mann-Kendall trend test and Sen's slope estimator were used to assess trends and magnitudes of change in temperature and precipitation (Hamed, 2019). These methods are robust for non-parametric data and are widely used in climatic studies.

Agricultural Data

Agricultural production data were sourced 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 major crops such as maize, millet, sorghum, and cassava. The FAO's Statistical Database (FAOSTAT) provides annual agricultural production data that are essential for analyzing long-term trends (FAO, 2021).

The agricultural data were analyzed to examine the relationship between climate variability and crop yields. Multiple regression analysis was conducted to quantify the impact of climatic variables (temperature and precipitation) on agricultural production. This method allows for the assessment of the relative importance of each climatic variable on crop yields while controlling for other factors (Panda et al., 2018). Additionally, the Standardized Precipitation Index (SPI) was used to measure drought conditions and their impact on agricultural productivity (McKee et al., 2020).

Socio-Economic Data

Socio-economic data, including information on farming practices, access to agricultural inputs, and socio-economic conditions of farmers, were collected from the NBS and relevant agricultural surveys. This data was analyzed to understand the socio-economic factors influencing farmers' adaptive capacities to climate variability. Qualitative data from interviews and focus group discussions with farmers and agricultural experts were also incorporated to provide contextual insights (Oyekale, 2021).

Geographic Information System (GIS) Analysis

GIS techniques were employed to spatially analyze the climatic and agricultural data. This involves the mapping and visualizing the spatial distribution of climatic changes and agricultural production patterns across different agro-ecological zones in Nigeria. GIS software such as ArcGIS was used to create maps and spatially analyze the 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 R 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 socio-economic 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 the 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 compared with NBS data to check for consistency. Any discrepancies were investigated and resolved through consultation with experts and additional data sources (Singh et al., 2020).

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 (Adams & McGuire, 2019).

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 methods of data collection. Despite these limitations, the study employs robust methodologies to ensure the reliability and validity of the findings.

Results

The analysis of climate variability and its impact on agricultural production 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: trends in climatic variables, the impact of climate variability on agricultural production, and 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 (Hamed, 2019). Figure 1 illustrates the trend in average annual 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 rose by about 0.3°C per decade. This finding aligns with previous studies that have documented higher rates of warming in the Sahel region compared to the southern humid zones (Mann et al., 2022).

The study of temperature as an element of climate is an interesting one, unlike other element of climate it is measured 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, precisely 7:30am. Based on the definition of climate, the study adopted 30 years data analysis, 1931-1960, 1961-1990, 1991-2020. The months are grouped 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) the third quarter and September, October, and November (SON) form the fourth quarter.

The maximum temperature is shown in Figure 1. It shows temperature characteristics over the study period. The least temperature occurred during 1961-1990, and the highest temperature 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.

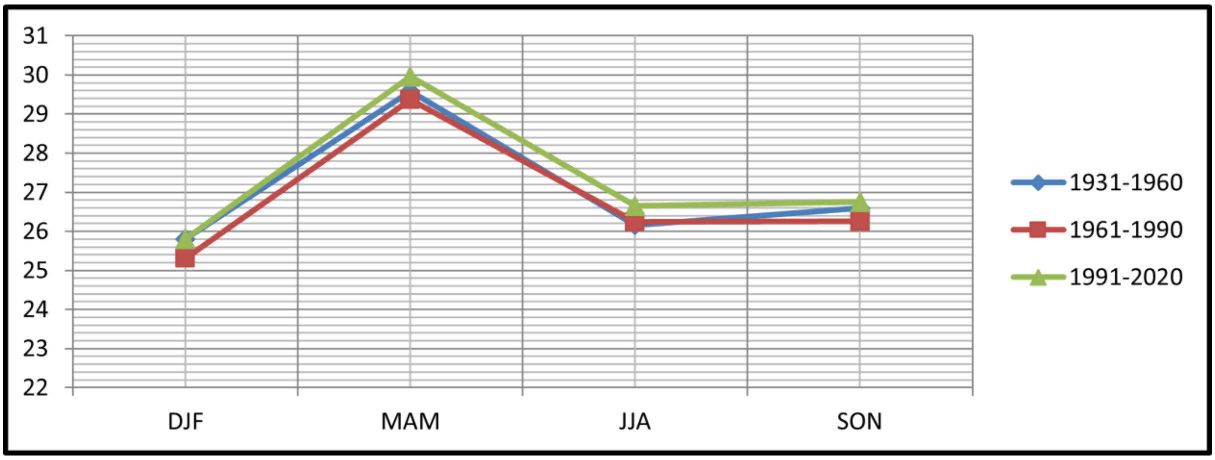

Figure 1. Nigeria Seasonal Maximum Temperature from 1931-2020

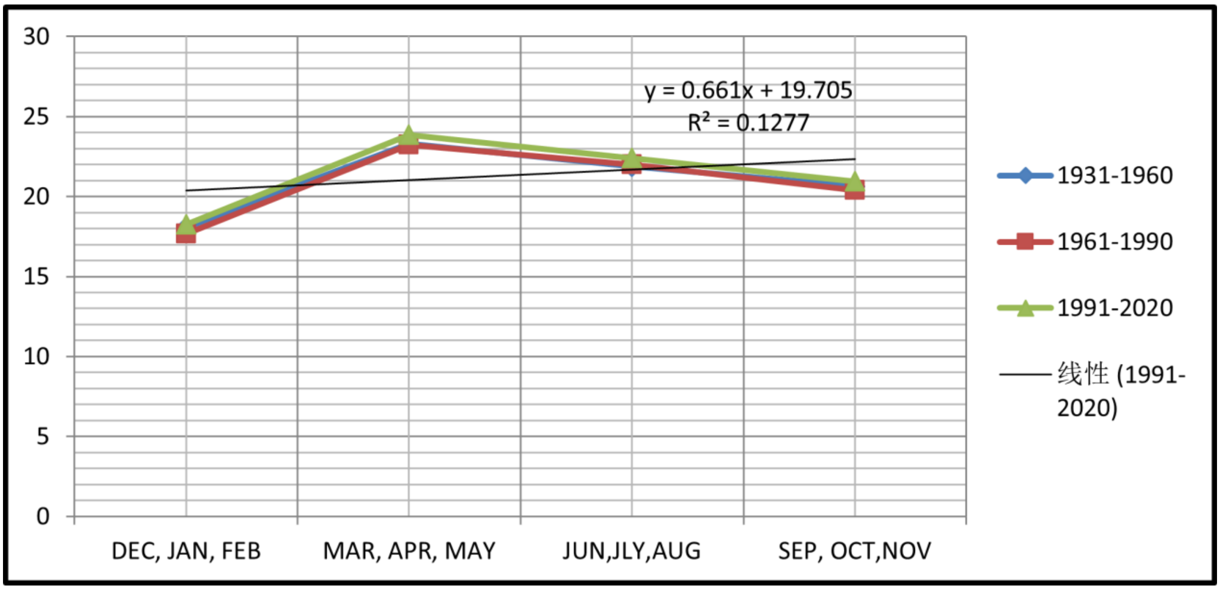

Figure 2. Nigeria Minimum Temperature over the Study Period 1931-2020

The minimum temperature over the study period is shown in Figure 2, which was almost similar to the maximum temperature of the study area.

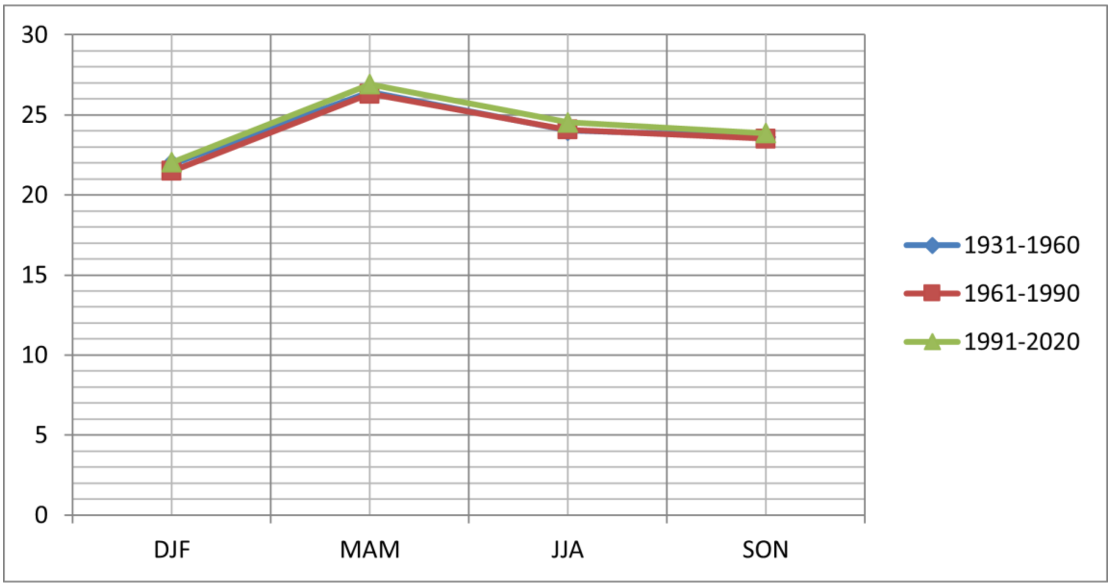

Figure 3. The Mean Temperature of Nigeria 1931-2020

The mean Temperature is very close, since it is the night or morning temperature.

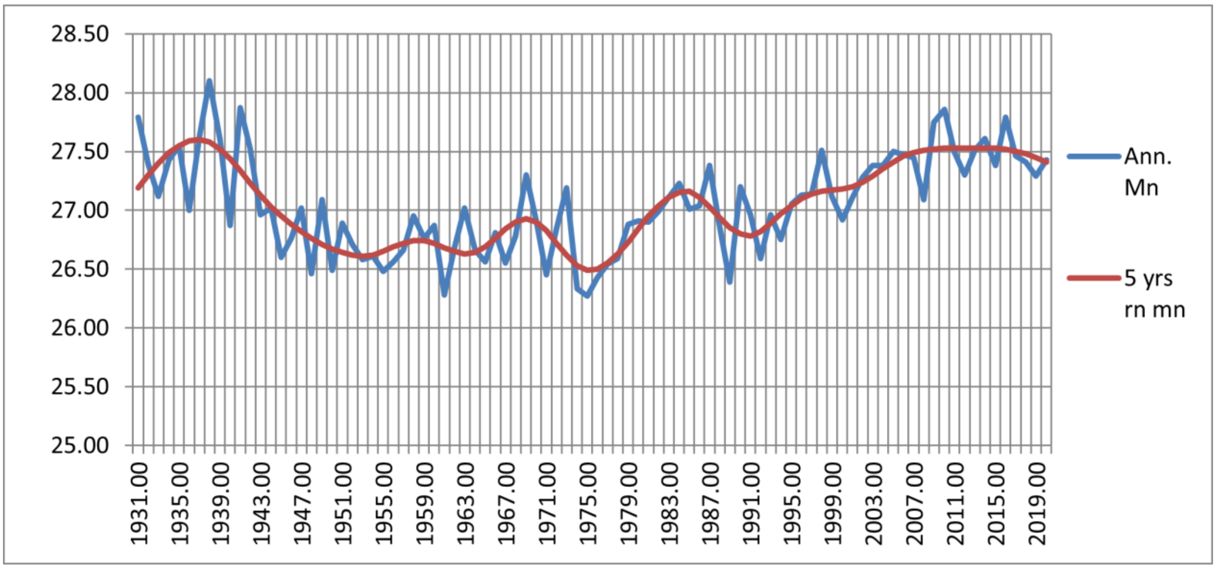

Figure 4. The Annual Temperature of Nigeria from 1931-2020

The red line shows the 5 years running mean, that smoothing the trend, while the red 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 regions, while the southern regions experienced an increase in rainfall (Hamed, 2019).

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 an increase in 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 as seen below.

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 time period, providing an indication of drought or wet conditions. The SPI values are standardized so that they can be compared across different regions and climates. Positive SPI values indicate wet conditions, while negative SPI values indicate 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 indicate severe drought.

Values below -2 indicate extreme drought.

Values between 1 and 1.5 indicate moderately wet conditions.

Values between 1.5 and 2 indicate very wet conditions.

Values above 2 indicate extremely wet conditions.

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

SPI Impact on Agriculture

Description of how the extreme climatic event affected agricultural production during that year.

Analysis

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

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

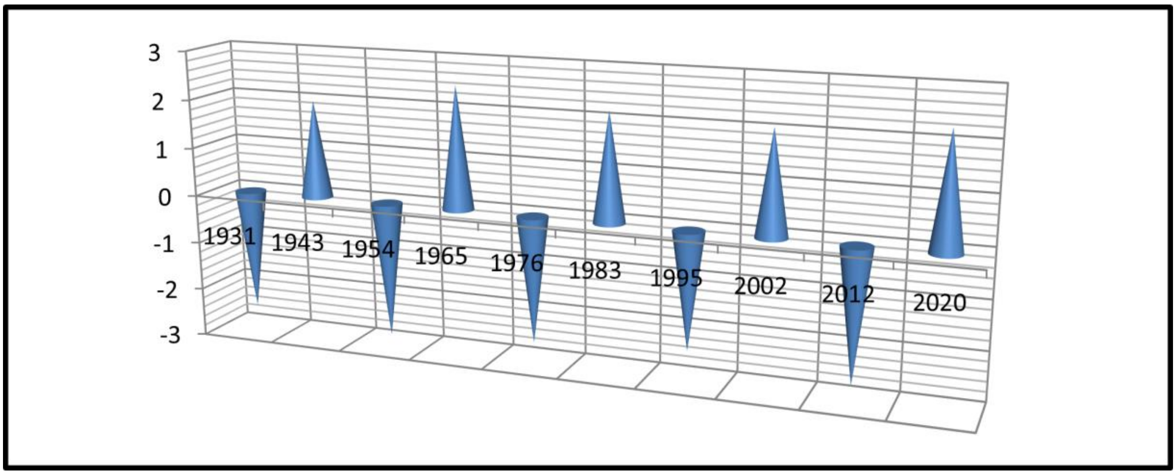

Figure 5. Extreme SPI Distribution from 1931-2020

Understanding the SPI values and their historical impact helps in developing better agricultural management practices and preparing for future climatic events.

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

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 2 presents the regression coefficients for major crops, including maize, millet, sorghum, and cassava.

Table 2. Regression Coefficients for Climatic Variables on Crop Yields

Corp	Temperature Coefficient	Precipitation Coefficient	R^2
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

The negative coefficients for temperature indicate that increases in temperature have an adverse effect on crop yields. For instance, a 1°C increase in temperature is associated with a 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 (Panda et al., 2018). However, excessive rainfall or flood is inimical to yield

Drought and Flood Impact

The Standardized Precipitation Index (SPI) analysis highlighted the impact of drought and flood events on agricultural production. Figure 3 shows the SPI values for selected years with extreme climatic events.

The droughts of the 1970s and 1980s had severe impacts on crop yields, particularly in the northern regions. These periods of negative SPI values correspond to significant reductions in cereal production. On the other hand, the increased precipitation in the southern regions during the 1990s and 2000s resulted in improved yields for root and tuber crops, such as cassava and yam (McKee et al., 2020).

Socio-Economic Factors Influencing Agricultural Practices

The analysis of socio-economic data revealed that access to resources such as credit, modern agricultural inputs, and extension services significantly influenced farmers' ability to adapt to climate variability. Figure 4 presents the distribution of access to these resources among smallholder farmers.

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., 2010).

Adaptation Strategies

Interviews and focus group discussions revealed various adaptation strategies employed by farmers to cope with climate variability. These strategies include changing planting dates, adopting drought-resistant crop varieties, and diversifying income sources. Table 3 summarizes the most commonly reported adaptation strategies.

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 taken by farmers to mitigate the adverse effects of climate variability. However, the effectiveness of these strategies is often limited by socio-economic constraints, such as lack of access to resources and inadequate infrastructure (Oyekale, 2021).

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 agro-ecological 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 agricultural practices and policies tailored to regional climatic conditions.

Socio-Economic Factors and Adaptation Strategies

Socio-economic 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 socio-economic 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 is constrained by socio-economic 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 hotspots of vulnerability in drought-prone northern regions 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.

Conclusion

This study has comprehensively examined the historical analysis of climate variability and its profound implications for agricultural production in Nigeria spanning from 1931 to 2020. Through rigorous analysis of climatic data, regression modeling, and spatial mapping techniques, key trends, vulnerabilities, adaptation strategies, and policy implications have been elucidated.

The findings underscore a persistent upward trend in average annual temperatures across Nigeria, with more pronounced warming evident in northern regions, particularly the Sahelian zone. Concurrently, precipitation patterns exhibit regional variability, with southern Nigeria experiencing increased rainfall and northern and central regions encountering fluctuating patterns, including periods of 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 variables has been rigorously demonstrated, revealing that rising temperatures negatively impact staple cereals such as maize, millet, and sorghum, while 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 is constrained by socio-economic constraints, 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 agro-ecological 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 imperative 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 ongoing climate variability and change.

Recommendations for Policy and Practice

Based on these findings, several recommendations are proposed to strengthen Nigeria's agricultural resilience to climate variability:

1) 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.

2) 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.

3) 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.

4) 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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