

NAVIGATING CLIMATE UNCERTAINTY: THE INFLUENCE OF RAINFALL VARIABILITY ON RICE PRODUCTION IN IKWO, NIGERIA

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Abstract: This study investigated the impact of climate change-induced rainfall variability on rice production in Ikwo Local Government Area (LGA), Ebonyi State, Nigeria. The study aimed to analyze rainfall patterns over three decades (1993-2023) and assess their implications for rice farming. Using a quantitative research design, secondary rainfall data was obtained from the Nigerian Meteorological Agency (NiMet). Statistical analyses were conducted to identify trends, anomalies, and changes in the onset and cessation of rainfall, as well as peak rainfall months. The findings revealed significant variability in annual rainfall totals, with high-rainfall years like 2022 (3886.7 mm) presenting risks of flooding and crop damage, while low-rainfall years like 2021 (1325 mm) were associated with drought and reduced productivity. Anomalies ranged from -593.91 mm (2021) to +1967.79 mm (2022) relative to a long-term mean of 1918.91 mm. The onset of rainfall fluctuated between January and March, while cessation varied from October to December, leading to irregular growing seasons. Peak rainfall typically occurred in July, August, or September, but variability in timing posed additional challenges for rice farmers. This study concluded that climate change has introduced significant uncertainties in rainfall patterns, threatening rice production in Ikwo LGA. It recommended climate-resilient farming practices, efficient water management, and improved meteorological data access to mitigate the effects of rainfall variability on agricultural productivity in the region.

Keywords: Change-Induced, Climate, Rainfall, Rice, Variability

I. Introduction

Climate change is one of the most pressing global challenges of the 21st century, with far-reaching impacts on various segments of human society, including agriculture. According to Habib-ur-Rahman et al., (2022), climate change is a threat already having substantial impact on human beings and the natural eco-system both in developed and developing countries but at varying degrees. For the developed countries, the impact of climate change has been perceived to be less severe. This as noted by Neo (2021) is due to natural advantage, high adaptation techniques, high technology, mechanized agricultural system and wealth status. These factors have enabled the developed economies to curtail the adverse effects of climate change. For developing countries like Nigeria, the impact of climate change is of great importance given the poor adaptation capacity, and lack of early warning system (Obioha, 2018).

The impact of climate change on the environment has been experienced globally, especially in the tropics. These have triggered a wide variety of physical and biological changes across the world. These changes exert negative effects on agriculture, humans, and the environment (Intergovernmental Panel on Climate Change, IPCC, 2018). According to Guntukula (2020), changes in the Earth's climate have significant consequences for agricultural systems worldwide. To buttress this view, Chandio, Magsi, and Ozturk (2020) asserted that the impact of climate change on important crops such as rice (*Oryza sativa*) and millet (*Panicum miliaceum*) may lead to food shortage in developing countries.

Rice is a staple food for billions of people worldwide, particularly in Asia and Africa, where it serves as a primary source of nutrition and livelihood for millions of small-scale farmers (Odeniyi, Ibitunde and Olaniyi, 2020). Evidently, agricultural crops production faces numerous challenges, with climate change emerging as a disruptive factor that exacerbates existing vulnerabilities. Erratic rainfall patterns and altered precipitation patterns directly affect crop growth and yields. From the foregoing, climate change poses a serious threat to the Nigerian economy due to high dependent of many Nigerians on substance farming. According to a World Bank Report (2019), Nigeria is one of the top ten exposed countries to the effects of climate change, with about 6% of its area estimated to be exposed to extreme weather events like flooding and drought. Although, the report focused on the whole country, the local economic dynamics suggest that the vulnerability varies across the country, with rural areas being mostly vulnerable.

It is against this backdrop that this study is focused on Ikwo local government area of Ebonyi state, which is a major rice production area in Ebonyi state Nigeria. A study by Onyeneke, Umeh, and Onyeneke, (2023) revealed that the area has experienced observable changes in weather patterns and an increase in climate-related challenges, such as prolonged droughts, heavy rainfall events, and unpredictable growing seasons. These changes are posing critical risks to rice farmers in the region, impacting their livelihoods and overall agricultural productivity. The importance of agriculture in Ikwo local government area cannot be overemphasized as it has contributed significantly to rice production in Nigeria. Nwachukwu (2023) noted that the area is one of the major rice production hub that gave Ebonyi state the status of rice producing state under the administration of President Buhari. While Nigeria has continued to battle shortage of rice and other grains like maize, leading to political debate as to whether to import grains or not, it is pertinent to look deeply inward and find the challenges that attenuate the productivity of the local farmers. Thus, the choice of Ikwo local government area for this study is predicated on this need to boost local production of rice by understanding the context specific challenges bedeviling local rice farmers.

As rightly asserted by Audu et al. (2017), rice farming, reliant on environmental elements, places paramount importance on some factors, which significantly influence agricultural output. The successful production of rice necessitates an optimal blend of production inputs to achieve high yields. These inputs extend beyond the conventional resources and include various environmental factors inherent in nature. Rainfall attributes such as intensity and duration, in addition to relative humidity and temperature, significantly impact both the yield and variability of rice production. While some factors are anticipated to enhance yield variance, others are expected to produce contrary effects (Eakin and Wehbe, 2020). Understanding the specific impacts of climate change on rice production in Ikwo LGA is crucial for developing targeted and effective adaptation and mitigation strategies. Such knowledge can inform policymakers, agricultural extension services, and other stakeholders about the urgent need to address climate change-related disruptions and build climate resilience within the rice farming sector.

II. REVIEW OF RELATED LITERATURE

2.1 Effect of Climate Change on Ikwo Agricultural System

Ikwo local government is one of the thirteen local government areas in Ebonyi state, Nigeria, and it is prominent for agriculture within the state. The people within the local government are mainly smallholder farmers who rely heavily on the proceeds of their farming for survival. Thus, it is understandable that such class of people are quite vulnerable to the menace of climate change. The influence of climate change on agricultural activities within the area accentuates the intricately localized outcomes engendered by shifts in the environmental milieu upon agricultural systems, indigenous livelihoods, and the broader socio-economic fabric. The agricultural setting of Ikwo LGA is characterized by its reliance on rain-fed farming and its cultivation of staple crops such as yam, cassava, rice and maize. The effects of climate change in this region are evident through shifts in precipitation patterns and rising temperatures (Diagi, 2018).

Understandably, altered rainfall patterns have a significant impact on agricultural activities in Ikwo LGA. Erratic and uneven distribution of rainfall disrupts the timing of planting and harvesting, which are critical to the success of rain-fed farming. This disruption leads to reduced crop yields, affecting both food security and economic stability for local farmers. Prolonged dry spells can lead to soil moisture depletion, hindering germination and growth of crops. Rising temperatures further compound the challenges faced by Ikwo LGA's agricultural sector. Elevated temperatures increase the risk of heat stress on crops, which can lead to diminished yields and lower crop quality. Heat stress also extends to livestock, with negative consequences for meat and dairy production. The local economy, largely dependent on agriculture, is susceptible to these impacts, potentially leading to reduced income and increased poverty rates.

Furthermore, Nwaka (2022) provided valuable insights into the effects of climate change on agricultural production and the livelihoods of rural households in Nigeria. The study utilized cross-sectional data to analyze the influence of climate change, revealing detrimental effects on both agricultural production and the well-being of rural households. The research identified several manifestations of climate change impacts, including diminished crop yields, increased incidents of pests and diseases, and more frequent and severe occurrences of droughts and floods. These consequences, in turn, had a notable impact on food security and poverty levels in Nigeria. The study emphasized the vulnerability of smallholder farmers, who faced challenges due to restricted access to essential resources such as land, water, and credit. Additionally, their limited ability to adopt climate-resilient agricultural practices made them more prone to crop losses and food insecurity.

Okoli and Okwuma (2022) in a study, which systematically reviewed existing data to investigate the impact of climate change on agricultural production and rural livelihoods in Nigeria, made a valuable contribution to the understanding of the challenges faced by rural households. The empirical review consistently highlighted the negative consequences of climate change on both agricultural production and the livelihoods of rural households in Nigeria. The study identified recurring effects, including decreased crop yields, increased occurrences of pests and diseases, and a higher frequency and intensity of droughts and floods. These combined impacts posed a significant threat to food security and exacerbated poverty issues in Nigeria's rural communities. The review also emphasized the heightened vulnerability of smallholder farmers, who faced challenges such as limited access to critical resources like land, water, and credit. Okoli and Okwuma's study underscored the difficulties smallholder farmers encountered in adopting climate-smart agricultural practices, further worsening their vulnerability and

increasing the likelihood of crop losses and food insecurity. The study contributes to the ongoing discussion by providing an empirical understanding of how climate change affects agricultural production and rural livelihoods in Nigeria.

The prominent concern within Ikwo Local Government Area (LGA) revolves around the intrinsic nexus between agriculture and the availability of water resources. Alterations in precipitation patterns, concomitant with heightened evaporation rates resulting from elevated temperatures, impose stress upon the indispensable water reservoirs essential for both agricultural irrigation and domestic utilization. This predicament imposes strain upon the extant water management frameworks. The socio-economic ramifications stemming from these challenges are of profound import. The considerable demographic proportion constituted by smallholder farmers within the confines of Ikwo LGA commonly confronts resource and informational paucities requisite for effective adaptation to the evolving climatic milieu. The ensuing decline in crop productivity and economic instability possess the capacity to further accentuate poverty prevalence and engender rural-to-urban migration.

Evident from the foregoing, climate change has been globally identified a threat to rice production, However, its specific impacts on varies across different regions, necessitating localised evaluation. Considering the significant important of rice production in the area, coupled with its reliance upon rain-fed agrarian endeavors, there is a pressing need to critically analyze the how climate induced rainfall pattern affects rice production in the area.

III. METHODOLOGY

3.1 Research Design

The study utilized a quantitative research design, which was deemed suitable for systematically examining the relationship between rainfall variability and rice production in Ikwo Local Government Area (LGA). This approach facilitated the collection of precise, measurable data that could be statistically analyzed to uncover trends, patterns, and correlations over time. By employing numerical data on annual rainfall from 1993 to 2023, sourced from the Nigerian Meteorological Agency (NiMet), the study ensured a robust foundation for identifying long-term changes in rainfall patterns and their implications for agricultural productivity. The design also allowed for the quantification of anomalies, trends in rainfall seasonality, and their direct impact on rice yields, providing actionable insights for addressing climate-related challenges in the region.

3.2 Area of Study

Ikwo is one of the thirteen (13) local government areas that make up Ebonyi state Nigeria. It is located at Ebonyi Central Senatorial Zone of Ebonyi State with its common boundaries at the, East – Cross River State, West – Ezza South L.G.A., North – Izzi L.G.A., and South – Onicha L.G.A. Ikwo local government area of Ebonyi state lies approximately within 5°40' and 6°45' north of the Equator and longitudes 7°30' and 8°30' east of the Greenwich meridian (Okorie et al., 2020). The local government area covers about 500 square kilometers (Ani, Maxwell, and Ecoma, 2017). The hydrology and water resources of Ikwo, Ebonyi State, Nigeria, are critical to the area's socio-economic development and environmental sustainability. Ikwo is predominantly drained by the Cross River and its tributaries, which form a dendritic drainage pattern in the lower courses and a parallel pattern in the upper courses (Onwe-Moses, Ozumba and Chijiuka, 2020). The river systems in Ikwo contribute significantly to the groundwater recharge and surface water availability, which are vital for agricultural activities, domestic use, and industrial operations.

IV. RESULTS AND DISCUSSIONS

This section presents key findings from this study, including annual rainfall trends, deviations from the long-term mean, changes in the onset and cessation of the rainy season, and variations in peak rainfall months. These insights provide a detailed understanding of how rainfall variability affects rice farming in the region.

4.1 Rainfall Anomalies (Difference from the Mean)

The first analysis entails a detailed breakdown of annual rainfall totals over a 31-year period (1993-2023). It compares each year’s rainfall to a calculated “long-term mean” and identifies how much each year deviates from that mean through “rainfall anomalies.”

Table 1: Rainfall Anomalies in Ikwo, Ebonyi state (Difference from the Mean) over the years from 1993 to 2023

Year	Total Rainfall (mm)	Mean Rainfall (mm)	Rainfall Anomaly (mm)
1993	1577.8	1918.91	-341.11
1994	1456.2	1918.91	-462.71
1995	2168.2	1918.91	249.29
1996	1919.7	1918.91	0.79
1997	2262.7	1918.91	343.79
1998	1497.0	1918.91	-421.91
1999	1508.2	1918.91	-410.71
2000	2018.1	1918.91	99.19
2001	1677.5	1918.91	-241.41
2002	1722.2	1918.91	-196.71
2003	1891.2	1918.91	-27.71
2004	1770.1	1918.91	-148.81
2005	1716.8	1918.91	-202.11
2006	2096.3	1918.91	177.39
2007	1911.2	1918.91	-7.71
2008	1793.0	1918.91	-125.91
2009	1634.2	1918.91	-284.71
2010	1669.5	1918.91	-249.41
2011	1729.3	1918.91	-189.61
2012	2137.7	1918.91	218.79
2013	1941.1	1918.91	22.19
2014	1929.6	1918.91	10.69
2015	2008.9	1918.91	89.99
2016	1882.5	1918.91	-36.41
2017	2071.3	1918.91	152.39
2018	1910.5	1918.91	-8.41
2019	1944.9	1918.91	25.99
2020	1893.6	1918.91	-25.31
2021	1325.0	1918.91	-593.91

2022	3886.7	1918.91	1967.79
2023	2535.2	1918.91	616.29

(Source: Nigeria Meteorological Agency, 2024)

The long-term mean is the average annual rainfall for the entire period from 1993 to 2023. It was calculated by summing all annual rainfall totals and dividing by the number of years (31 in this study).

$$\text{Long – Term Mean} = \frac{\sum \text{Total Rainfall over 31 years}}{31} \tag{1}$$

Thus, the long term means is approximately 1918.91 mm. The "Mean Rainfall" column in the table contains the same value (1918.91 mm) for each year. This provides a consistent benchmark against which the rainfall for any given year can be assessed. Each year’s rainfall is compared to this benchmark to determine if it was wetter or drier than average. The “Rainfall Anomaly” column shows the difference between the actual rainfall of a particular year and the long-term mean. It’s calculated as:

$$\text{Rainfall Anomaly} = \text{Total Rainfall for Year} - \text{Long – Term Mean} \tag{2}$$

When the anomaly is positive (above 0), the rainfall for that year was higher than the long-term mean, indicating an unusually wet year. On the other hand, When the anomaly is negative (below 0), the rainfall was lower than the average, indicating a drier year.

For example:

In 1995, the total rainfall was 2168.2 mm. The anomaly is calculated as:

2168.2–1918.91=249.29 mm. This positive anomaly means 1995 was wetter than the average year. Conversely, in 1994, the total rainfall was 1456.2 mm, which is: 1456.2–1918.91 = 462.71 mm. This negative anomaly means 1994 was much drier than average.

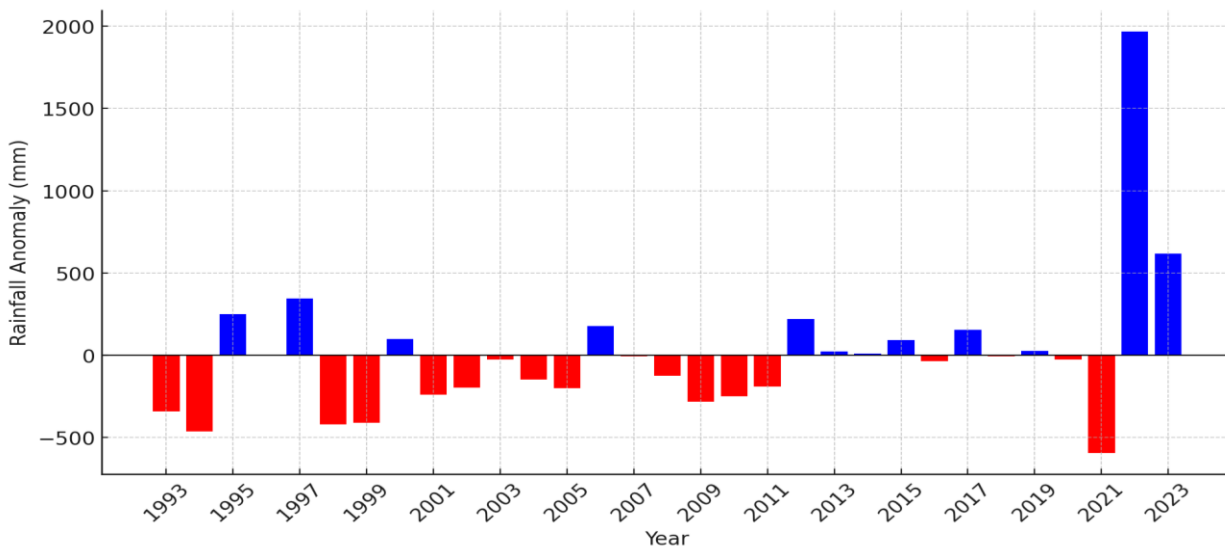


Figure 1: Rainfall Anomalies of Ikwo, Ebonyi state relative to long-term mean (1993-2023)

The rainfall anomaly chart (Figure 1) presents a visual analysis of annual deviations from the long-term average rainfall over a 31-year period from 1993 to 2023. This figure captures the extent of variability in annual rainfall, highlighting both wetter and drier than average years in Ikwo LGA, Ebonyi State, Nigeria. Positive bars above the zero line represent years with rainfall above the long-term mean of 1918.91 mm, while negative bars below the line indicate years with rainfall below this average. Such a visualization allows for an immediate recognition

of extreme deviations that may have had significant impacts on agricultural productivity, particularly rice farming, which is heavily dependent on rainfall.

The analysis reveals notable fluctuations, with certain years exhibiting considerable positive anomalies, such as 1997, 2012, and especially 2022, the latter showing the highest anomaly and indicating an exceptionally wet year. These peaks could correspond to years with higher rice yields, assuming that other conditions such as flooding did not adversely affect production. Conversely, there are pronounced negative anomalies in years like 1994, 1998, and 2021, suggesting significantly drier conditions than average. Such years could be associated with decreased yields due to inadequate water supply, stressing the sensitivity of rice crops to rainfall availability.

The variation in rainfall anomalies over time also indicates potential underlying climatic trends or shifts. Periods of high variability, with consecutive years of positive or negative anomalies, suggest broader environmental changes that could influence future rice cultivation strategies in Ikwo. Identifying such patterns is essential, as they provide insights into years that deviated sharply from the norm. This enables a more subtle understanding of how rainfall impacts agricultural outcomes. This analysis underscores the importance of rainfall pattern monitoring for anticipating and mitigating the effects of climate variability on rice production.

4.2. Annual rainfall totals over the years from 1993 to 2023

The second statistical analysis that was conducted using the rainfall data of Ebonyi state was to determine the annual rainfall totals over the years from 1993 to 2023. The results of this analyses are presented in Table 1 and Figure 2.

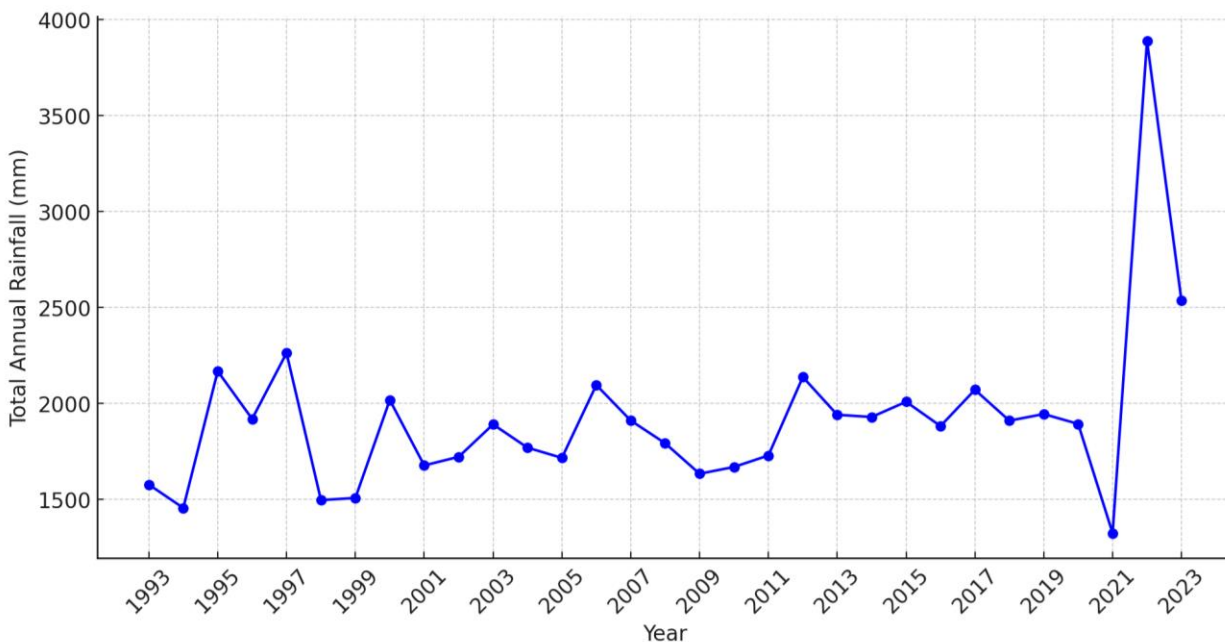


Figure 2: Annual rainfall trends in Ikwo LGA, Ebonyi state, Nigeria (1993 – 2023)

The rainfall data from 1993 to 2023 reveals significant year-to-year variability in total annual rainfall, with both high and low extremes. High-rainfall years, such as 1995, 1997, 2006, 2012, and especially 2022, recorded substantially more rainfall compared to the long-term average. These high-rainfall years can be beneficial for rice production, as rice crops typically require a substantial water supply to thrive. However, excessively high rainfall can also lead to flooding, which might damage the crops, delay planting and harvesting schedules, and ultimately reduce rice yield. Conversely, years like 1994, 1998, 1999, and particularly 2021 experienced significantly lower

rainfall, potentially resulting in insufficient water availability for rice fields. These drought-like conditions could stress rice crops and lead to a decrease in productivity.

Analyzing the overall pattern, it is challenging to pinpoint a consistent long-term trend of increasing or decreasing rainfall, but there are noticeable phases within the data. Between 1993 and 2000, rainfall levels show moderate to high variability, but with fewer extremes. The period from 2001 to 2010 appears relatively stable, with totals generally between 1600 and 2000 mm, although some years had occasional peaks. From 2011 onward, there are larger fluctuations, including record highs and lows, such as the substantial rainfall in 2022 and the sharp decrease in 2021. These fluctuations suggest a possible influence of climate variability, which may impact water availability for rice fields in unpredictable ways. The apparent increase in extreme values during recent years could signal a shift toward more volatile rainfall patterns, a likely consequence of climate change.

In particular, the high variability in rainfall levels observed from 2011 to 2023 highlights the challenges that rice farmers may face in managing water supply. Extreme high rainfall years like 2022 and 2023 posed risks of flooding, which might damage rice crops or cause waterlogging, affecting root health and growth. Conversely, years with lower rainfall, such as 2021, may not provide enough water for optimal rice production, underscoring the potential for both drought and flood risks.

In conclusion, moderate and consistent rainfall is typically ideal for rice cultivation, as it ensures sufficient water without the hazards of flooding or drought. However, the observed trend of increased rainfall variability in recent years suggests that rice production in Ikwo LGA may face heightened challenges in the future.

4.3 Analysis of The onset (first month) and cessation (last month) of rainfall

The third analysis aimed to evaluate the onset (first month) and cessation (last month of rainfall) in the study area over the years from 1993 to 2023. The essence of this analysis is to find out whether there has been fluctuations in the rice farming seasons as a result of erratic rainfall pattern over the years.

Table 3: The onset (first month) and cessation (last month) of rainfall in Ebonyi state (1993-2023)

YEAR	ONSET (FIRST MONTH)	CESSATION (LAST MONTH)
1993	FEB	DEC
1994	JAN	NOV
1995	JAN	NOV
1996	JAN	OCT
1997	JAN	DEC
1998	FEB	OCT
1999	FEB	DEC
2000	JAN	NOV
2001	FEB	NOV
2002	FEB	NOV
2003	JAN	NOV
2004	JAN	NOV

2005	JAN	DEC
2006	JAN	OCT
2007	FEB	NOV
2008	JAN	DEC
2009	JAN	NOV
2010	MAR	NOV
2011	JAN	NOV
2012	JAN	NOV
2013	JAN	DEC
2014	JAN	NOV
2015	FEB	NOV
2016	JAN	NOV
2017	JAN	NOV
2018	FEB	NOV
2019	FEB	NOV
2020	FEB	OCT
2021	FEB	NOV
2022	FEB	OCT
2023	JAN	NOV

(Source: Nigeria Meteorological Agency, 2024)

The rainfall Seasonality Plot for the years 1993 to 2023 is shown in Figure 3, with the onset and cessation months. The blue line with circular markers indicates the onset month, while the red line with circular markers represents the cessation month.

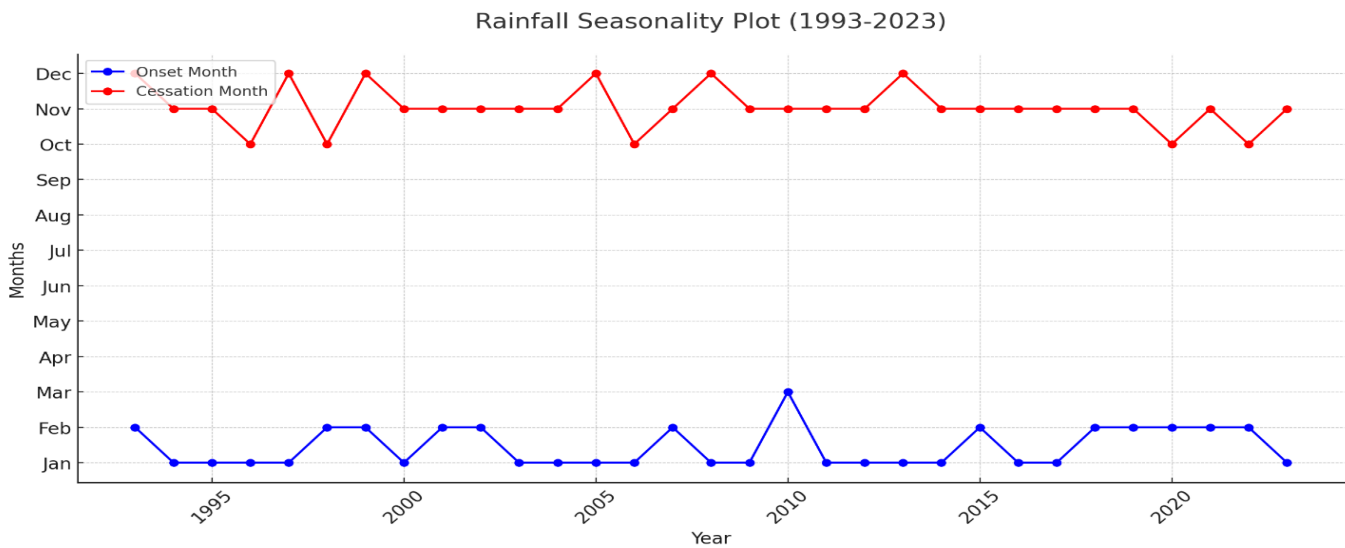


Figure 3: Rainfall Seasonality Plot of Ebonyi state for the years 1993 to 2023, showing the onset and cessation months.

This analysis of rainfall seasonality in Ikwo LGA, from 1993 to 2023, shows significant variability in the onset and cessation of the rainy season. This is central to understanding the impact of climate change on rice production

in the region. As illustrated by the table and line plot, the onset of rainfall generally fluctuates between January and February, with occasional deviations, such as a delayed onset in March 2010. Similarly, the cessation of rainfall varies between October and December. Thus, there is an unpredictable length of the growing season that could directly affect crop yields. These variations are indicative of shifting rainfall patterns likely driven by climate change. This introduces additional challenges for rice farmers reliant on a stable water supply for optimal crop growth.

The graph highlights that the early onset months, primarily in January, support an extended rainy season in some years, potentially beneficial for water-dependent crops like rice. However, inconsistencies in onset and cessation months, such as years when the rains begin as late as March or end as early as October, reduce the effective growing season. This irregularity not only affects the timing of rice planting but also the maturity and yield potential of rice crops, which require predictable rainfall patterns for maximum productivity. The data reveals a trend toward more frequent late onsets and early cessations over time. Given this, there is an increased risk of water stress, especially if late-season rains are insufficient to sustain crop growth through harvest. Such shifts could drive farmers toward adaptive measures, such as altered planting schedules or crop variety changes, to mitigate yield loss due to rainfall variability.

4.4 Determination of the Month with Highest Recorded Rainfall

The analysis was taken further to ascertain the months with the highest record rainfall over the years (1993-2023) in the study area. The essence of this analysis is to know whether there has been substantial variations that could affect rice farming in the study area. The analysis provided insights into peak rainfall patterns crucial for understanding optimal planting periods and potential climate-induced shifts in rainfall distribution in Ikwo LGA. It involved examining both the frequency and distribution of peak rainfall months over time and their variations. The analysis revealed that the peak rainfall months are largely concentrated in the months of July, August, and September, with occasional peaks occurring in June and October, and a rare instance in March (2004). These peak months align closely with the traditional rainy season. The periods are marked by intense rainfall likely beneficial for rice cultivation. However, this intense rainfall also potentially contributes to risks of waterlogging or flooding, depending on the field management and drainage capabilities in place.

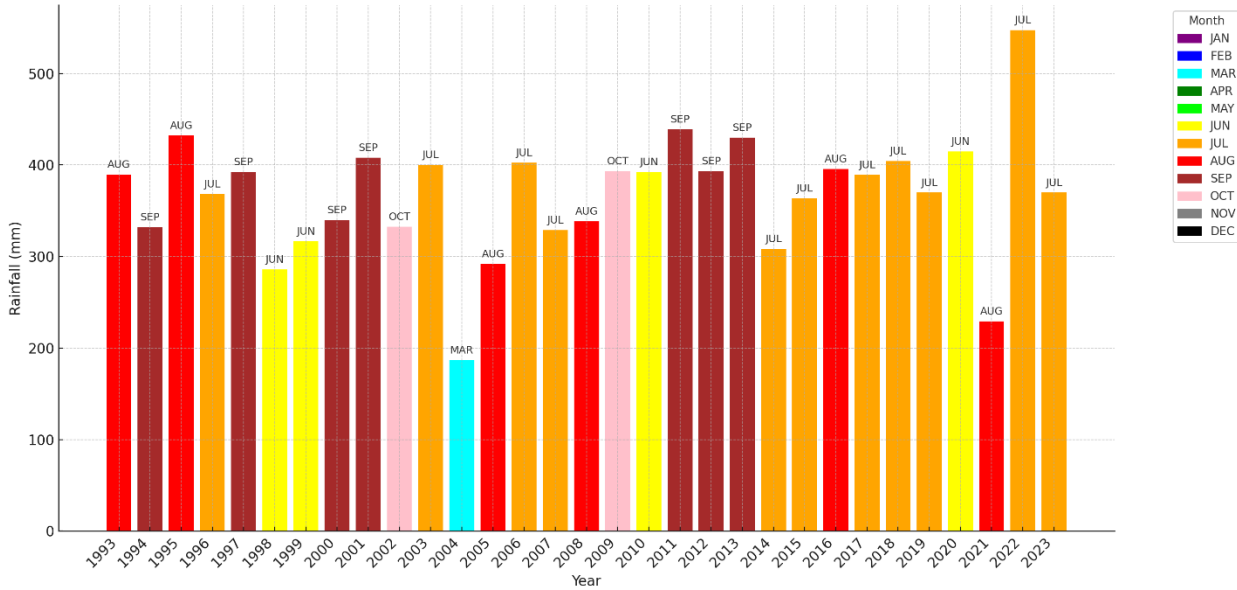


Figure 4: A bar chart showing the month with the highest recorded rainfall for each year from 1993 to 2023.

The bar chart (Figure 4.4) highlights significant patterns in annual rainfall distribution in Ikwo LGA, from 1993 to 2023. This record reveals that the highest monthly rainfall varies across different months over the years. There are particular months, such as July, August, and September that frequently record peak rainfall levels. These trends are critical when assessing the disruptive potential of climate change on rice production, given that rice is highly sensitive to changes in rainfall patterns.

For rice farmers in Ikwo, the unpredictability and variation in peak rainfall months pose a substantial challenge. Traditionally, rice farming relies on consistent seasonal rainfall patterns to guide planting, growth, and harvesting cycles. The data shows, however, that peak rainfall does not occur consistently within a specific month year after year. For instance, while July is often the month with the highest recorded rainfall, other years see peaks in August, September, or even October. This variation could lead to irregular soil moisture levels and potential flooding during critical periods in the rice cultivation cycle, particularly during planting or maturation phases, thereby affecting crop yields.

From a climate change perspective, these irregularities in peak rainfall months and volumes may suggest a shift in local climate dynamics. Climate change is known to impact rainfall patterns globally. It often results in extreme weather events, including prolonged dry spells, unexpected heavy rainfall, and shifts in seasonal rainfall. Such fluctuations could disrupt traditional farming calendars. Thus, it is challenging for farmers in Ikwo to rely on historical data or experience when timing their activities. As evident from the data, irregular peak rainfall patterns may lead to greater risks of crop damage from both drought and excessive waterlogging, which are detrimental to rice crops. This disruption aligns with broader patterns of climate change that are often associated with increased variability in weather and precipitation patterns.

V. CONCLUSION

The study investigated the impact of climate change-induced rainfall variability on rice production in Ikwo Local Government Area (LGA), Ebonyi State, Nigeria. Over a 31-year period (1993-2023), the analysis revealed significant fluctuations in annual rainfall patterns. While high-rainfall years, such as 2022, presented opportunities

for increased crop yields, they also carried risks of flooding, which can disrupt planting and damage crops. Conversely, drought-like years, including 2021, posed significant challenges due to insufficient water availability, likely leading to lower rice productivity. These patterns underscore the critical sensitivity of rice cultivation to rainfall consistency. Moreover, the study identified shifting trends in the onset and cessation of rainfall seasons. The rainy season in Ebonyi state, Nigeria generally begins between March and April and ends between October and December. However, irregularities in these timings, such as delays in rainfall onset or earlier cessation, have shortened the effective growing season, disrupting traditional planting schedules and affecting crop maturation. This unpredictability poses significant challenges for smallholder farmers reliant on consistent rainfall patterns. Analysis of peak rainfall months further highlighted variability, with most peak rainfall occurring in July, August, or September, though some years showed peaks in June or October. This variability complicates agricultural planning, as rice farming depends heavily on stable rainfall during key growth stages. Unpredictable water availability can lead to issues such as waterlogging, which damages crops, or inadequate moisture, which stunts growth.

The findings suggest that climate change has introduced significant uncertainty into the agricultural framework of Ikwo LGA, threatening rice production. Adapting to these challenges will require targeted interventions, such as developing climate-resilient rice varieties, implementing efficient water management systems, and providing timely meteorological data to support farmers in optimizing planting and harvesting cycles. These measures are critical for sustaining rice production and enhancing food security in the region.

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