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A TEMPORAL ANALYSIS OF RAINFALL PATTERNS AT THE UNIVERSITY OF JOS: IMPLICATIONS FOR AGRICULTURE AND CLIMATE RESILIENCE

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Abstract

This study investigates the Temporal Analysis of Rainfall Patterns at the University of Jos and Its Implications on Agriculture and Climate Resilience. The aim was to assess temporal changes in rainfall patterns over the past 30 years (1995–2024) and their implications for climate resilience in the region. The study adopted a quantitative research methodology, utilizing secondary rainfall data collected from the University of Jos Meteorological Weather Station. Descriptive statistics, including mean, standard deviation, and coefficient of variation (CV), were used to analyze the rainfall data. Additionally, the seasonality index (SI) and linear regression models were employed to assess rainfall concentration and long-term trends. The theoretical framework was informed by climate change adaptation and vulnerability-resilience theories. The findings revealed significant fluctuations in annual rainfall, with a range from 1,036.9 mm to 1,991.6 mm, and a mean of 1,398.4 mm. The regression analysis indicated a weak negative trend ($Y = -1.5094x + 4427.7$), suggesting a slight decline in annual rainfall, though the coefficient of determination ($R^2 = 0.0031$) highlighted that local climatic factors play a significant role in the observed variability. The seasonality index ranged from 0.47 to 0.84, indicating a distinct seasonal distribution of rainfall. The onset of rainfall varied from late February to mid-May, and the cessation occurred between late September and early December, with a mean rainy season length of 197 days. The study concluded that increasing rainfall variability, influenced by both local topography and broader climate change dynamics, poses significant challenges to agricultural sustainability. Therefore, the study recommends the adoption of climate-resilient agricultural practices, enhanced water resource management, improved climate forecasting, and policy development to ensure long-term agricultural sustainability and food security. Further research is essential to investigate the long-term implications of these changes.

***Keywords**: Agricultural productivity, Climate change, Rainfall variability & Sustainability*

Introduction

Rainfall, a critical component of the Earth's climate system, is inherently variable both spatially and temporally, driven by a combination of natural processes and human-induced changes. In recent decades, global climate patterns have exhibited increased volatility, exacerbating concerns regarding the impacts on agricultural systems, water resources, and urban infrastructure (Ajayi & Balogun, 2021). Climate change refers to the long-term shifts in weather patterns, as evidenced by persistent alterations in temperature, precipitation, and extreme weather events over extended periods (IPCC, 2019). Rainfall, as a form of precipitation, plays a vital role in sustaining various ecosystems, ensuring the availability of water for domestic, agricultural, and industrial purposes. In particular, rainfall patterns in tropical regions, including sub-Saharan Africa, significantly influence agricultural productivity, which remains a primary source of livelihood for millions (Fadiran & Owoyemi, 2022).

The importance of rainfall goes beyond its immediate utility as a water source. Its temporal variability directly impacts the growing seasons of crops, hydropower generation, and the timing of critical agricultural activities such as planting and harvesting (Akinola & Adewumi, 2020). The reliability, intensity, and frequency of rainfall are crucial for optimal crop yields, making its study an essential aspect of climate science, particularly in regions dependent on rain-fed agriculture. In sub-Saharan Africa, where agriculture forms the backbone of the economy, variations in rainfall can trigger significant socio-economic disruptions, including food insecurity, displacement, and increased poverty rates (Zabawa & Ndikumana, 2021). Rainfall variability is even more pronounced in regions where the onset and cessation of rainy seasons are unpredictable, as seen in the University of Jos area, situated in Nigeria’s central region.

Globally, the effects of climate change on rainfall patterns have been a major subject of investigation. For instance, a study by Zhang et al. (2020) highlighted a general increase in the frequency of extreme rainfall events worldwide, alongside a decline in the predictability of seasonal rainfall. However, the geographical disparities in rainfall trends are noteworthy, with some regions experiencing higher precipitation, while others face prolonged dry spells.

This phenomenon has led to calls for region-specific studies on climate impacts, particularly in areas with high agricultural dependency, such as sub-Saharan Africa. In Africa, rainfall patterns have shown a trend of declining precipitation in the Sahel region and an increase in rainfall variability in East Africa (Moseley & Williams, 2022). These shifts in rainfall characteristics have not only disrupted food production but have also intensified the challenges of climate adaptation in vulnerable regions.

In the context of Nigeria, the country's varied climate zones experience significant fluctuations in rainfall, with some areas benefiting from stable rainfall patterns, while others suffer from erratic and unpredictable weather conditions. The central region of Nigeria, which includes the University of Jos, is particularly vulnerable to these changes. As one of the key agricultural hubs, this region has seen significant disruptions in farming due to the altered rainfall patterns (Oluwole & Fashola, 2021). The irregularities in rainfall, marked by delayed onset, early cessation, and fluctuating intensity, have led to reduced crop yields, affecting food security and livelihoods in the region. These challenges are exacerbated by the lack of adequate water management systems and infrastructure, further hindering the ability of local communities to adapt to changing climatic conditions (Usman et al., 2023).

Given the significance of rainfall for agricultural productivity, understanding the trends and variations in rainfall in the University of Jos area is crucial for developing effective strategies to mitigate the impacts of climate change. Research into the temporal characteristics of rainfall is an essential component of climate adaptation planning. By analyzing long-term data on rainfall variability, local farmers and policymakers can gain insights into patterns of climate resilience and vulnerability, thereby enhancing preparedness for future climatic uncertainties. Moreover, accurate knowledge of rainfall trends provides critical information for water resource management, disaster preparedness, and the development of sustainable agricultural systems in the region. In recent years, there has been growing concern about the unpredictable nature of rainfall in Nigeria's central region.

The University of Jos, located within this region, has witnessed disruptions in its local farming activities due to irregular rainfall patterns.

This unpredictability in the timing and intensity of rains has made it increasingly difficult for farmers to determine the optimal planting and harvesting times, leading to crop failure and food shortages (Ezekiel & Okafor, 2020). Furthermore, the increasing frequency of droughts and floods has exacerbated the challenges faced by the local agricultural sector, further threatening food security and economic stability in the region.

To better understand the rainfall patterns in the University of Jos area, it is essential to conduct a temporal analysis that examines both the long-term trends and short-term variability of rainfall. Such an analysis allows for the identification of potential shifts in rainfall behavior over the past decades, providing the necessary foundation for adapting agricultural practices to changing climatic conditions. The objective of this study is, therefore, to assess the variability and trends in annual rainfall data for the University of Jos area over a 30-year period, from 1993 to 2023. This research aims to identify the key characteristics of rainfall, including the timing, frequency, and intensity, and their implications for the region's agricultural productivity.

The temporal analysis of rainfall in the University of Jos area is not only important for local agricultural development but also for broader climate change adaptation strategies in the region. Understanding the changing rainfall patterns in this area can help inform future policy decisions on water resource management, agricultural planning, and climate resilience initiatives. Given the central role of rainfall in sustaining both the natural environment and human livelihoods, examining these trends is a vital step towards ensuring a more resilient and sustainable future for the University of Jos and its surrounding communities.

2.1 Conceptual Review

2.1.1 Rainfall Variability

Rainfall variability refers to the unpredictable fluctuations in rainfall characteristics, such as its intensity, frequency, timing, and duration, which can vary across different seasons and regions (Nwogu & Eze, 2022). In regions like sub-Saharan Africa, these variations are particularly impactful on agriculture, where optimal crop production relies on consistent rainfall patterns. The unpredictability of rainfall can significantly disrupt farming schedules, leading to reduced agricultural productivity, lower crop yields, and increased vulnerability to food insecurity (Johnson & Akinwumi, 2021). Understanding how rainfall fluctuates over time is crucial for assessing its potential impacts on both water resources and agricultural systems.

2.1.2 Climate Change

Climate change is defined as a long-term alteration in climate patterns, often characterized by persistent shifts in temperature and precipitation (Akinbo & Akinwale, 2020). These shifts are primarily driven by human-induced factors like deforestation and urbanization, as well as natural phenomena such as volcanic activity and changes in solar radiation (IPCC, 2021). The increased volatility in weather patterns, including irregular rainfall, has profound implications for regions dependent on rain-fed agriculture. In places like Nigeria, where agriculture constitutes a major livelihood, climate change exacerbates the uncertainty of rainfall, thus affecting food production, water resources, and overall socio-economic stability (Mogaji & Madu, 2022).

2.1.3 Agricultural Productivity

Agricultural productivity is directly influenced by rainfall patterns, as reliable rainfall is essential for crop growth, irrigation, and overall food security (Olaniyi & Adedeji, 2021).

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The seasonal timing and consistency of rainfall are key factors that determine the success of crops in tropical regions like Nigeria, where a significant proportion of the population relies on rain-fed agriculture (Akinola & Balogun, 2020). Changes in rainfall intensity and frequency can affect planting and harvesting times, leading to crop failures and increased food insecurity. As climate patterns continue to shift, understanding the link between rainfall variability and agricultural outputs is vital for enhancing food production and socio-economic resilience.

2.1.4 Water Resource Management

Effective water resource management is crucial in regions affected by rainfall variability, as changing patterns can lead to water shortages or excesses, disrupting both domestic and agricultural water supplies (Okoro & Usman, 2020). In regions like the University of Jos, where water scarcity is often compounded by irregular rainfall, effective management is necessary to ensure water is available for irrigation, domestic use, and hydropower (Aliyu & Ibrahim, 2021). This challenge is particularly relevant in areas where the lack of infrastructure limits water storage and distribution capacity, making sustainable water resource management essential for adapting to climate variability.

2.1.5 Climate Resilience

Climate resilience refers to the capacity of communities and agricultural systems to adapt to climate-related challenges and bounce back from environmental stresses, such as changing rainfall patterns (Adeyemo & Okanlawon, 2022). This involves improving agricultural practices, enhancing water management, and developing strategies for disaster preparedness (Ogunbiyi & Taiwo, 2023). In the context of the University of Jos and similar regions, promoting climate resilience is key to ensuring sustainable livelihoods and food security in the face of increasingly unpredictable rainfall and extreme weather events.

2.3 Theoretical Review

The Climate-Change Adaptation Theory (Mogaji & Madu, 2022; Adeyemo & Okanlawon, 2022) centers on the capacity of systems and communities to adjust to the shifts in climate and variability. The theory assumes that societies, particularly those dependent on agriculture, can mitigate climate impacts by employing adaptive strategies, such as altering agricultural practices and adopting innovative technologies. In regions like the University of Jos, where rainfall variability is pronounced, adaptation becomes essential to safeguard food security and water availability. The application of this theory is particularly pertinent in understanding how local agricultural communities can adjust to irregular rainfall patterns, including the use of drought-resistant crops, early planting, and the optimization of water resources. While the theory emphasizes resilience and adaptability, critics argue that its focus on adaptation alone may overlook the root causes of climate change, such as anthropogenic emissions. Despite this, the theory remains crucial for framing the strategies needed to manage shifting rainfall patterns and ensuring agricultural productivity. Its relevance to the study lies in providing a foundation for understanding how the University of Jos community, and agricultural systems in particular, can adapt to changing rainfall patterns to minimize their vulnerability to food insecurity and water shortages.

Similarly, the Vulnerability-Resilience Framework (Johnson & Akinwumi, 2021; Ogunbiyi & Taiwo, 2023) delves into the relationship between climate stressors, such as irregular rainfall, and the community's capacity to recover from these disturbances. The theory assumes that societies with strong resilience mechanisms can better cope with the adverse effects of climate variability, while vulnerable communities may face more severe impacts. This framework is directly applicable to the study of the University of Jos region, as it provides insight into how vulnerable agricultural systems can be made resilient to rainfall uncertainties through effective water management, climate information dissemination, and adaptive farming practices. Critics, however, contend that the framework oversimplifies the complexity of vulnerability, particularly in regions where economic and social disparities hinder access to resilience-building resources. Nonetheless, this framework remains valuable in the context of the study as it allows for the identification of key factors contributing to agricultural vulnerability and resilience. Its application aids in understanding how the agricultural systems of the University of Jos can strengthen their capacity to withstand and recover from changing rainfall patterns, ultimately contributing to sustainable agricultural practices in the face of climate change.

In conclusion, both the Climate-Change Adaptation Theory and the Vulnerability-Resilience Framework are crucial to understanding the challenges and opportunities faced by

agricultural systems in the University of Jos area. The theories underscore the need for strategic adaptation and resilience-building in response to rainfall variability, offering valuable frameworks for guiding local agricultural policies and practices. Their application within this study helps frame the agricultural sector's response to climate-induced rainfall changes, providing insights that could inform both policy and practical interventions aimed at ensuring food security and sustainable agricultural productivity.

2.4 Empirical Review

Chike, Adebayo, and Okeke (2024) investigated the impact of rainfall variability on agricultural productivity in Northern Nigeria. The aim of the study was to assess how changes in rainfall patterns affect crop yields and food security in the region. The study adopted a longitudinal methodology, utilizing satellite data and local rainfall records over a 25-year period. The findings revealed that erratic rainfall patterns led to significant disruptions in the timing of planting and harvesting seasons, reducing crop yields by up to 30%. The study concluded that rainfall variability was a major determinant of food insecurity in the region, and recommended the development of drought-resistant crops and better water storage systems to mitigate the impacts of climate change on agriculture.

Akinloye, Tunde, and Bello (2023) examined the role of rainfall trends in shaping the agricultural landscape of South-western Nigeria. The study aimed to determine whether increasing rainfall variability had led to shifts in crop choice and farming practices.

Using a combination of econometric models and climate data, the researchers found that the frequency and intensity of extreme rainfall events were positively correlated with changes in crop production, with farmers adapting by shifting to more resilient crops such as cassava and yam. The study concluded that adapting to changing rainfall patterns could enhance agricultural resilience, and recommended the introduction of climate-smart agriculture policies and improved forecasting systems for farmers.

Musa, Adamu, and Gimba (2022) explored the relationship between rainfall irregularities and water resource management in the Jos Plateau region. The objective of the study was to investigate how changes in rainfall distribution affected the availability of water for irrigation, domestic use, and hydropower generation. The study adopted a mixed-methods approach, combining quantitative analysis of rainfall data and qualitative interviews with local farmers and water managers. The findings indicated that unpredictable rainfall led to a mismatch between water availability and agricultural needs, exacerbating water scarcity issues. The study concluded that efficient water resource management strategies, including rainwater harvesting and improved irrigation techniques, were critical for sustaining agriculture in the region, and recommended stronger collaboration between local authorities and farmers in water management practices.

Olufemi, Hassan, and Salim (2021) investigated the socio-economic impacts of rainfall fluctuations on agriculture in Nigeria's central region, with a focus on the University of Jos area. The aim was to assess how the irregular timing and intensity of rainfall influenced both crop yields and farmers' livelihoods. Utilizing a survey methodology and analyzing rainfall data from 1990 to 2020, the researchers found that the irregular onset and cessation of rains caused widespread crop failures, particularly for rain-fed crops like maize and sorghum. The study concluded that the agricultural sector was highly vulnerable to rainfall changes, and recommended the development of climate-resilient farming practices, such as the use of drought-resistant seeds and better land management techniques.

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Vol. 1 No. 1, November, 2025. Pg 1 - 23
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3.1 Methodology

The Study Area

The university of Jos is located in Jos North Local Government Area of Plateau State. The university lies between latitude 9º52' - 10º00'N and longitude 8º50' - 8º56'E, at an elevation of about 1,100m above sea level. The university has two major campuses which are at Bauchi road and its permanent site along Farin Gada road. The area experiences a tropical montane climate characterized with two distinct seasons, wet and dry. The wet season spans a period of 6 months (May to October), while the dry season covers from November to April. The mean annual rainfall stand at about 1,261mm with temperatures ranging from 16.3ºC and 28.1ºC (Alfa et al., 2022).

Figure 1: Map of Study Area

3.2 Data Collection

The research made use of a secondary rainfall data collected from the University of Jos Meteorological Weather Station. The data span a period of 30 years (1995 - 2024). The dataset comprised daily and monthly rainfall records used to compute key rainfall parameters. A rain day according to Nigeria Meteorological Organization is a period where moisture that is collected exceed 0.25mm, anything below that is recorded as Trace - "TR."

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Vol. 1 No. 1, November, 2025. Pg 1 - 23
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3.3 Data Analysis

The rainfall data collected was subjected to a descriptive statistic of mean, standard deviation, and coefficient of the variation (CV). The Annual rainfall totals were derived by aggregating monthly values. The mean monthly rainfall is the summation of the rainfall value occurring during the study period derived by the number of years or month as the case be. This expressed as:

$$\bar{x} = \frac{\sum x}{N} \qquad (1)$$

The standard deviation which is the square root of the mean is measures the dispersion around the mean of the variable. It is expressed as

$$\sigma = \frac{\sum (X - \bar{X})^2}{N} \qquad (2)$$

The coefficient of the variation measures percentage deviation from the mean which is also expressed as

$$\text{CV} = \frac{\sigma}{X} \times 100\% \qquad (3)$$

The six major rainfall characteristics which the study considered were annual rainfall amount, annual rainfall trend, seasonality index, onset and cessation dates, length of the rainy season, and rainfall duration.

3.3.1 Onset, Cessation Dates, Length of Rain Days, and Length of Rainfall Duration:

The onset date of rain is the time a pace receives an accumulated amount of rainfall which sufficient to enable the growth of crops. It is not the first day that the rain falls. Cessation of rainfall dates refers to the termination of the effective rainy season. It is the time when the rainfall can no longer support plant growth. Both onset and cessation dates of rainfall are key factors that controls the calendar of agricultural activities in any give area or place.

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The length of rain days (LRD) refers to the total number of days within a given period on which measurable rainfall occurs. The length of rainfall duration (LRS) refers to the difference between the number of days between the onset and cessation dates for each year. To determine onset of rainfall, Walter (1967), Binbol et al. (2016), and Griffith (1972) employed different statistical methods to determine the onset, cessation, and length of rain days. For this study, the onset and cessation of rainfall in the University of Jos were computed using the Walter's (1967) method because it is simple and accurate. The formula is expressed as follows:

$$\text{Days in the month}\left[\frac{51-accumulated\ rainfall\ of\ previous\ months}{Total\ rainfall\ for\ the\ month}\right] \quad (4)$$

3.3.2 Determination of Rainfall Seasonality Index (SI):

For this research, the seasonality index (SI) proposed by Walsh and Lawler (1981) was used to evaluate the degree of rainfall concentration and the extent of seasonal variation in the study area. This expressed as: $\mathrm{SI} = \frac{1}{R}\sum\left[X_n - \frac{R}{12}\right]$ (5)

Where; SI = Seasonality Index

Xn = Mean rainfall of months

R = Mean annual rainfall

3.3.3 Annual Rainfall Trend

The annual trend was analyzed using time series and descriptive statistical techniques. A linear regression model (Y = a+bx) was applied to determine the direction of change in annual rainfall in the study area.

4.1 Results and Discussions

Table 1 presents a descriptive statistic of the various variables that this study investigates. Rainfall was analyzed for a period of 30 years. The minimum annual rainfall recorded was 1,036.9mm in year 2007 while the highest amount of annual rainfall recorded was 1, 991.6

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in year 2019. The average rainfall for the 30-year period is 1,398.4mm with a standard deviation of 260.7mm. This indicates that annual variability remains significant. To establish the annual trend pattern of variability of annual rainfall, Microsoft Excel was used to plot the 30 years rainfall data.

Table 1: Descriptive statistics for variables under study

	N	Minimum	Maximum	Mean	Std. Deviation
Annual Rainfall (mm)	30	1,036.9	1,991.6	1398.4	260.7
Seasonality Index (SI)	30	0.47	0.84	0.65	0.09
Length of Rain Days	30	58	126	94.6	14.9
Length of Rainy Season	30	146	292	196.8	34.9
Onset of Rainfall	30	69	138	100.5	17.6
Cessation of Rainfall	30	271	335	293.4	14.8

Source: Authors compilation using SPSS software

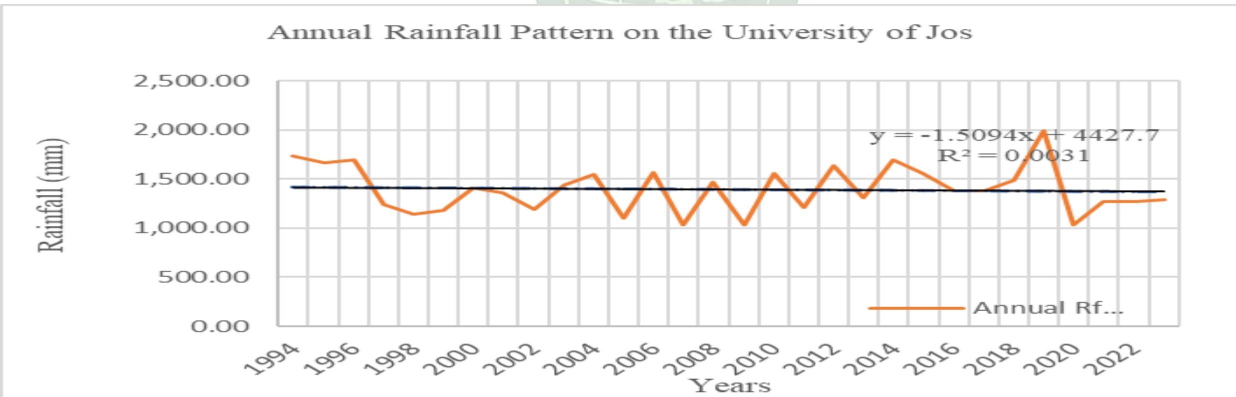

Figure 2. Annual Rainfall of the University of Jos

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4.1.1 Rainfall Characteristics on the University of Jos

Annual Rainfall

In 1994, there was a drastic increase, followed by a slight decline in 1995. By 1996, the amount of rainfall remained high, though a downward trend started appearing. 1997 and 1998 continued this decline, with rainfall dropping further. 1999 and 2000 marked some of the lowest rainfall levels during this period, showing a sharp reduction compared to earlier years. As the 2000s progressed, rainfall began to fluctuate. 2001 and 2002 saw slightly improved rainfall levels compared to the late 1990s. However, 2003 and 2004 experienced another dip before 2005 and 2006 recorded moderate increases. In 2007, rainfall declined significantly, marking one of the lowest levels in the dataset. 2008 and 2009 saw a significant fluctuation. In the 2010s, rainfall continued to vary. 2010 and 2011 recorded moderate levels, followed by an increase in 2012, which saw another peak. 2013 and 2014 had slightly reduced rainfall, but 2015 and 2016 saw another rise. In 2016 to 2018, rainfall maintained a stable pattern. 2019 saw the highest peak of rainfall in the whole 31 years. 2020 witnessed a sharp decrease compared to the peak year. This downward trend continued into 2021, 2022, and 2023.

4.1.2 Annual Variability Model

To establish the annual pattern of annual rainfall variability, Microsoft excel package was used to plot a 30 years annual rainfall from the dataset. The is presented on figure 2. The plot showed a regression trend line and findings indicated that despite the fluctuating nature of rainfall in the study area, rainfall seems to be decreasing. This is demonstrated by the regression equation that was generated Y= -1.5094X + 4427.7, the correlation coefficient indicated that rainfall (X) increased by 593.3mm above the mean in the wettest year which was 42.4% higher than the mean annual rainfall and rainfall in the driest year dropped by 361.5mm below the mean which was 25.9% lower than the mean annual rainfall. The R^2 value of 0.0031 indicated that only 0.31% of rainfall variation can be explained by time, affirming that the variation of rainfall in the study area is largely influenced by local or

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micro-climatic factor. This finding confirmed Abel and Amachigh's (2024) finding in Yola, Adamawa State, where a decreasing rainfall rate of -7.23mm per year was reported. Similarly, Ishaku, Daura, and Gabriel (2024) found mixed rainfall trends across North-Eastern Nigeria, with some slight declines in some areas and minimal declines being experienced in other areas which indicated regional climatic variability. These contrasting results highlight the spatial heterogeneity nature of rainfall patterns in Nigeria, which is shaped by local environmental factors, topography, and regional climate systems.

4.1.3 Seasonality Index of Rainfall on the University of Jos

Based on Walsh and Lawler's (1981) categorization of seasonality index which is as follows:

SI < 0.19 – Rainfall is evenly distributed throughout the year.

0.20 ≤ SI < 0.39 – Weakly seasonal with rainfall spread across most months.

0.40 ≤ SI < 0.59 – Seasonal but still relatively well-distributed.

0.60 ≤ SI < 0.79 – Markedly seasonal rainfall, with distinct wet and dry periods.

0.80 ≤ SI < 0.99 – Strongly seasonal with a short-wet season.

SI ≥ 1.00 – Extremely seasonal, with a highly concentrated wet season.

The seasonality index of rainfall in the University of Jos presented in tabel 2 fluctuates between 0.47 and 0.84 over the years. With reference to Walsh and Lawler's categorization, most of the values fall within the markedly seasonal rainfall (0.60 – 0.79) category, while a few years exhibit strongly seasonal patterns (0.80 – 0.99). Years with markedly seasonality (0.60 – 0.79) includes 1996 (0.65), 1999 (0.66), 2000 (0.73), 2003 (0.71), 2011 (0.66), 2014 (0.67), and 2022 (0.71). These years indicate a distinct wet and dry season, but rainfall remains relatively spread across multiple months. Years with strongly seasonal rainfall (0.80 – 0.99) include 2008 (0.84), 2015 (0.81), and 2018 (0.78), which indicate a shorter wet season and prolonged dry periods. The high seasonality index recorded from 2015 through 2018 is a clear indicator of the impact of climate change on rainfall characteristics on the university of Jos.

4.1.4 Onset and Cessation of Rainfall

The onset date refers to when the rainy season begins each year, while the cessation date marks when it ends. Findings indicated that the onset of rainfall varies between late February (55 days) and mid-May at (138days). For the cessation of rainfall, findings indicated that it ranges from late September at (271 days) to early December at (335days). Although, the rainfall onset dates fluctuated by up to months, the cessation dates remained relatively consistent, see Table two. The variability in both onset and cessation reflects the heightening impact of climate change. Its irregularities align with the broader climate change patterns across tropical regions, where fluctuations in the movement of the Inter-Tropical Discontinuity (ITD) and temperature alter rainfall timing and its intensity.

4.1.5 Length of Rain Days (LRD)

The Length of rain days refers to the number of days within the rainy season when measurable rainfall actually occurred. Findings indicated that lowest amount of rain days was recorded in 2010 with 58 rain days and the highest in 1994 with 126 rain days. The mean length of rain days is 95 days. See Table 2. The variability associated with climate change is leaving its footprint on rainfall associated parameters.

4.1.6 Length of Rainy Season (LRS)

The length of rainy season is the difference between the cessation and onset of the rainfall. Findings from the analysis indicated that there was fluctuation in the duration of effective rainfall, since the length of rainy season is 197 indicating rainfall generally lasts for more than half of the year. The longest rainy season was recorded in 2019 with 292 days while the short rainy season was recorded in 2016 with 146 days. The period of high rainy season indicated years of higher moisture available, while the years with lower rainy season indicated years of climatic instability.

Table 2: Summary of Rainfall Characteristics on the University of Jos

Years	Annual Rf (mm)	S.Index	Onset Dates	Cessation Dates	Length of Rain Days	Rainfall Duration
1994	1,731.70	0.47	3rdApril(93days)	30th Oct(300days)	126	207
1995	1,662.70	0.47	14th April(104days)	7th Oct(280days)	93	176
1996	1,696.40	0.65	12th Mar(88days)	13th Oc(286days)	107	198
1997	1,236.40	0.61	13th May(133days)	7th Nov(311days)	102	178
1998	1,142.80	0.53	18th April(108days)	21st Oct(294days)	98	186
1999	1,183.10	0.66	12th Mar(71days)	15th Oct(288days)	105	217
2000	1,409.40	0.73	19th Mar(95days)	9th Oct(282days)	107	187
2001	1,361.50	0.62	1st Apr(91days)	5th Oct(278days)	81	187
2002	1,196.10	0.69	18th Mar(77days)	18th Oct(271days)	99	194
2003	1,434.40	0.71	11th April(101days)	8th Nov(309days)	107	208
2004	1,550.90	0.63	3rd Mar(93days)	24th Oct(294dsys)	100	201
2005	1,101.60	0.57	21st Apr(111days)	15th Oct(288days)	94	177
2006	1,565.80	0.62	24th April(114days)	18th Oct(291days)	106	177
2007	1,036.90	0.67	10th Mar(69days)	19th Oct(292days)	104	223
2008	1,470.70	0.84	9th Mar(99days)	4th Dec(335days)	92	236
2009	1,037.90	0.63	4th April(94days)	23rd Oct(293days)	58	217
2010	1,553.50	0.55	17th Mar(76days)	29th Oct(299days)	105	223
2011	1,207.70	0.66	1st Mar(91days)	22nd Oct(292days)	76	201
2012	1,633.40	0.67	4th April(92days)	18th Oct(271days)	93	179

2013	1,306.10	0.54	1st April(91days)	3rd Oct(274days)	84	183
2014	1,694.20	0.67	1st Mar(91days)	19th Oct(271days)	95	180
2015	1,558.90	0.81	12th April(101days)	15th Oct(288days)	89	187
2016	1,379.00	0.66	5th May(125days)	21st Sept(271days)	94	146
2017	1,379.50	0.63	18th May(138days)	24th Oct(294days)	68	156
2018	1,491.40	0.78	10th May(130days)	11th Oct(284days)	97	154
2019	1,991.60	0.59	24th Feb(72days)	27th Oct(297days)	99	292
2020	1,037.00	0.68	12th April(101days)	14th Oct(287days)	73	186
2021	1,272.00	0.57	7th April(99days)	20th Oct(293days)	85	194
2022	1,269.20	0.71	10th April(94days)	15th Oct(288days)	89	194
2023	1,289.60	0.69	5th April(95days)	6th Oct(279days)	83	184

The above Table revealed that The rainfall characteristics for the University of Jos area from 1994 to 2023 show considerable inter-annual variability, with annual rainfall fluctuating between 1,036.9mm in 2007 and 1,991.6mm in 2019. The average annual rainfall of 1,398.4mm highlights significant variations, consistent with the unpredictable climate patterns observed globally. The seasonality index, ranging from 0.47 to 0.84, indicates that rainfall is generally seasonal, though some years exhibit more concentrated wet seasons, while others have more evenly distributed rainfall. This shift in seasonality is in line with broader climate change trends. Onset and cessation dates also show considerable irregularity, with rainfall starting as early as March and as late as May, and ending anywhere from late September to December. Such fluctuations further emphasize the erratic nature of rainfall patterns, which has implications for agricultural productivity. The number of rain days and the length of the rainy season also vary significantly, contributing to the unpredictability of rainfall in the region. These shifts underscore the challenges posed by climate change, as they can lead to crop failures, water shortages, and disruptions in farming. Adaptation through improved farming practices, resilient crops, and better water management is essential for sustaining agricultural productivity and food security.

4.2 Discussion of Findings

The findings from this study on rainfall variability at the University of Jos underscore significant fluctuations in rainfall patterns over the past 30 years, which aligns with the empirical reviews and theoretical frameworks discussed earlier. The descriptive statistics show that while the minimum recorded annual rainfall was 1,036.9mm in 2007, the highest level was 1,991.6mm in 2019, with a mean of 1,398.4mm. This significant variability reflects the impact of broader climatic changes, as seen in the work of Chike, Adebayo, and Okeke (2024), who found similar disruptions in planting and harvesting schedules due to erratic rainfall in Northern Nigeria. The variability of rainfall observed here is indicative of unpredictable and fluctuating patterns, which directly impact agricultural productivity, as demonstrated in the study by Olufemi, Hassan, and Salim (2021) on the socio-economic impacts of rainfall fluctuations in Nigeria's central region, including the University of Jos area.

Furthermore, the analysis reveals a noticeable downward trend in rainfall over the study period, corroborating the findings of Abel and Amachigh (2024) and Ishaku, Daura, and Gabriel (2024), who reported regional declines in rainfall across parts of Nigeria. The regression analysis confirmed that while the fluctuating nature of rainfall in the region is notable, there is a gradual decrease, with years of higher rainfall becoming increasingly rare. The R^2 value of 0.0031 suggests that this variability is largely driven by micro-climatic factors rather than larger temporal trends, supporting the argument that local environmental elements, as highlighted in the Vulnerability-Resilience Framework, play a central role in rainfall distribution (Johnson & Akinwumi, 2021; Ogunbiyi & Taiwo, 2023).

In relation to the seasonality index, the study found that most years exhibited marked seasonality (0.60 to 0.79), reflecting the predictable wet and dry periods typical of the region. However, years like 2008, 2015, and 2018 showed stronger seasonality (0.80 to 0.99), indicating more distinct rainy and dry seasons. This shift towards stronger seasonality is consistent with the broader trends identified in the Climate-Change Adaptation Theory, where adaptive strategies are essential to mitigating the impact of increasing unpredictability in rainfall patterns (Mogaji & Madu, 2022). The fluctuations in onset and cessation dates also highlight the growing unpredictability of rainfall, which is in line with the findings of Akinloye, Tunde, and Bello (2023), who showed that shifts in rainfall timing lead to changes in crop production practices. The irregular onset and cessation of rains in the University of Jos area—ranging from February to May for onset and September to December for cessation—reflect the larger patterns of climate change discussed by Akinbo and Akinwale (2020), where irregularities in rainfall behavior disrupt agricultural systems dependent on precise timing.

Additionally, the variability in the length of rainy days and the duration of the rainy season further emphasizes the shifting climate conditions. The longest rainy season recorded was in 2019, with 292 days, while the shortest was in 2016 with only 146 days, indicating significant climatic instability. These findings resonate with the conclusions of Musa, Adamu, and Gimba (2022), who highlighted that unpredictable rainfall creates mismatches between water availability and agricultural needs, leading to water scarcity and crop failures. The variability in these parameters aligns with the Vulnerability-Resilience Framework's focus on the capacity of agricultural systems to cope with climate stresses. As these changes in rainfall characteristics directly affect water availability for irrigation, domestic use, and hydropower generation, efficient water resource management becomes even more critical, as discussed in the theoretical framework.

In conclusion, the findings from the University of Jos rainfall analysis reflect a clear pattern of increased variability and changing rainfall characteristics, which are consistent with global climate change trends. The study supports the empirical conclusions of Chike, Adebayo, and Okeke (2024) and Olufemi, Hassan, and Salim (2021), while also aligning with the theoretical concepts of climate change adaptation and vulnerability-resilience.

The increasing unpredictability of rainfall, coupled with shifts in seasonal patterns and water availability, underscores the need for adaptive strategies and resilience-building mechanisms in agricultural systems. As highlighted by the theoretical frameworks, communities in the University of Jos area must develop strategies that enhance their capacity to cope with these changes, which is vital for ensuring agricultural productivity and food security in the face of ongoing climatic shifts. This study contributes valuable insights into the growing impact of climate change on the region's rainfall and calls for further research to assess the long-term implications of these changes, providing a foundation for policy interventions that will support climate resilience and sustainable agricultural practices.

5.1 Conclusion

The study concluded that the analysis of rainfall variability at the University of Jos reveals significant fluctuations in rainfall patterns over the past 30 years, consistent with broader climate change trends affecting Nigeria. Annual rainfall has exhibited considerable variability, with the highest recorded in 2019 (1,991.6mm) and the lowest in 2007 (1,036.9mm), reflecting the unpredictability and erratic nature of rainfall. This variability has had direct implications on agricultural productivity, aligning with empirical studies that highlight disruptions in planting and harvesting schedules due to erratic rainfall. The seasonality index also shows shifts from moderately seasonal to strongly seasonal patterns, further reinforcing the growing unpredictability of rainfall. Additionally, fluctuations in onset and cessation dates and the length of rainy days indicate increased climatic instability, affecting water availability for irrigation and domestic use. These findings emphasize the need for adaptation strategies to enhance resilience in the face of shifting climatic conditions. The study underscores the urgency of addressing the challenges posed by climate change to agricultural systems, advocating for the development of climate-resilient practices

and efficient water resource management to ensure food security and sustainable productivity in the region.

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5.2 Recommendations

1. **Climate-Resilient Agricultural Practices**: Farmers should be encouraged to adopt drought-resistant crops and implement adaptive techniques, such as changing planting schedules, to cope with the growing unpredictability of rainfall.
2. **Water Resource Management**: There is an urgent need to improve water management practices, including the introduction of rainwater harvesting systems and efficient irrigation technologies, to mitigate the impact of fluctuating rainfall on agricultural productivity.
3. **Enhanced Climate Forecasting**: Policymakers should invest in accurate and accessible climate forecasting systems to help farmers make informed decisions about planting and harvesting, reducing the risks posed by irregular rainfall patterns.
4. **Policy and Community Engagement**: Local authorities and agricultural communities should collaborate to develop policies and practices that promote climate adaptation, resilience, and sustainable agricultural development, ensuring long-term food security.
5. **Further Research**: Continued research into the long-term impacts of rainfall variability and climate change on agriculture is essential for understanding future trends and informing policy interventions aimed at building climate resilience in the region.

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