
TREND ANALYSIS OF TEMPERATURE AND RAINFALL IN JEMA'A LOCAL GOVERNMENT AREA OF KADUNA STATE, NIGERIA

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ABSTRACT

This study examines long-term trends and variability in rainfall and temperature in Jema'a Local Government Area of Kaduna State, Nigeria, over 56 years (1970–2025). The Mann-Kendall trend test and Theil-Sen slope estimator were used to analyse annual rainfall and maximum and minimum temperature data from the Nigerian Meteorological Agency to determine the direction, magnitude, and significance of climatic changes. The findings indicated a slight increase in annual rainfall ($Z = 1.28$; Sen's slope = $+5.63$ mm/year). Rainfall varies significantly from year to year, with periods of above- and below-average precipitation interspersed with a discernible increase in 2023. Over the study period, maximum temperatures show a slight, statistically insignificant downward trend ($Z = -0.67$; Sen's slope = -0.018 °C/year), indicating that daytime temperatures have remained largely constant. In contrast, minimum temperatures show a statistically significant declining trend ($Z = -2.87$; Sen's slope = -0.051 °C/year), suggesting that nighttime temperatures are steadily declining. Overall, the findings suggest that climatic variability has a stronger influence on local climate patterns in Jema'a LGA than long-term trends. These changes have important implications for agriculture, water resource management, and environmental sustainability in the area. Continuous climate monitoring and targeted adaptation strategies are therefore essential to support farming communities and enhance resilience to climate variability.

Keywords: Climate Change, Rainfall, Temperature, Pattern

INTRODUCTION

Climate variability and climate change are widely recognised as major environmental challenges affecting both natural and human systems worldwide. Changes in climate patterns have become increasingly evident across many regions (Salinger, 2005). Temperature and rainfall changes are among the most reliable indicators of climate change. They directly affect ecosystem stability, water availability and agricultural production. (Hatfield et al., 2020). Scientific studies show that long-term climate change is associated with rising global temperatures and alterations in precipitation patterns (Mohammed, 2005). These changes pose real challenges for developing countries that depend on rainfall for farming (Abebaw, 2025). Fluctuations in rainfall and temperature can significantly affect evapotranspiration rates, soil moisture, crop yields, and the frequency of droughts and floods we face (Ariko, Ikpe, Yerima, Abdulkadir, & Abukur, 2024).

Trend analysis of hydro-climatic variables provides important scientific evidence for detecting changes in climate behaviour over time (Peter, 2025). Through statistical analysis of long-term



meteorological data, researchers can identify whether climatic variables exhibit increasing, decreasing, or stable trends (Richifa, et al., 2025). Such information is essential for understanding the impacts of climate variability and for developing appropriate adaptation strategies.

Nigeria is particularly susceptible to climatic variability because most people rely on agriculture and other livelihoods sensitive to climate change (Dogo, et al., 2025). Recent observations indicate rising temperatures and irregular rainfall across several parts of the country, threatening food security and water availability. Despite these concerns, there is limited climate trend study on rainfall, particularly and other climate variabilities in many areas, including parts of Kaduna State (Ogbu, Manoba, & Limantol, 2023).

Understanding long-term rainfall and temperature patterns is therefore essential for climate risk management, agricultural planning (Tadama, 2024), and sustainable resource use. This study examines the long-term trends and variability of rainfall and temperature in Jema'a Local Government Area of Kaduna State from 1970 to 2025 using the Mann–Kendall trend test and the Sen's slope estimator.

The study aims to determine whether significant climatic changes have occurred over time and to assess their potential implications for environmental sustainability and agricultural productivity in the study area.

MATERIAL AND METHODS

Study Area

Jema'a Local Government Area (Figure 1) lies between latitude 9°10'N and 9°30'N and longitude 8°00'E and 8°30'E. It is bounded by Kaura Local Government Area in the northeast, Zangon-Kataf in the north, Jaba in the northwest and Sanga in the south and southeast. The area lies at an elevation of approximately 563.88 m above sea level and covers about 1,384 km² (Magaji, 2020).

The climate is characterised by a tropical wet and dry season. The average annual temperature is about 25.2°C, with average maximum temperatures around 28.6°C and minimum temperatures around 18.8°C (Dachung, Peter, Agera, & Ekhuemelo, 2025). The area's climate is influenced by the orographic effects of the Jos Plateau and the Kagoro Hills, which shape rainfall distribution and atmospheric circulation. Average annual precipitation is about 1800mm (Abaje & Usman, 2010). The region also experiences the dry Harmattan wind between November and February. The vegetation is predominantly Guinea Savanna, and the soils are mainly ferruginous tropical soils suitable for agricultural activities. Agriculture is the primary occupation of the inhabitants, with major crops including sorghum, maize, cassava, millet, and ginger (Abaje, Sawa, Iguisi, & Ibrahim, 2016).

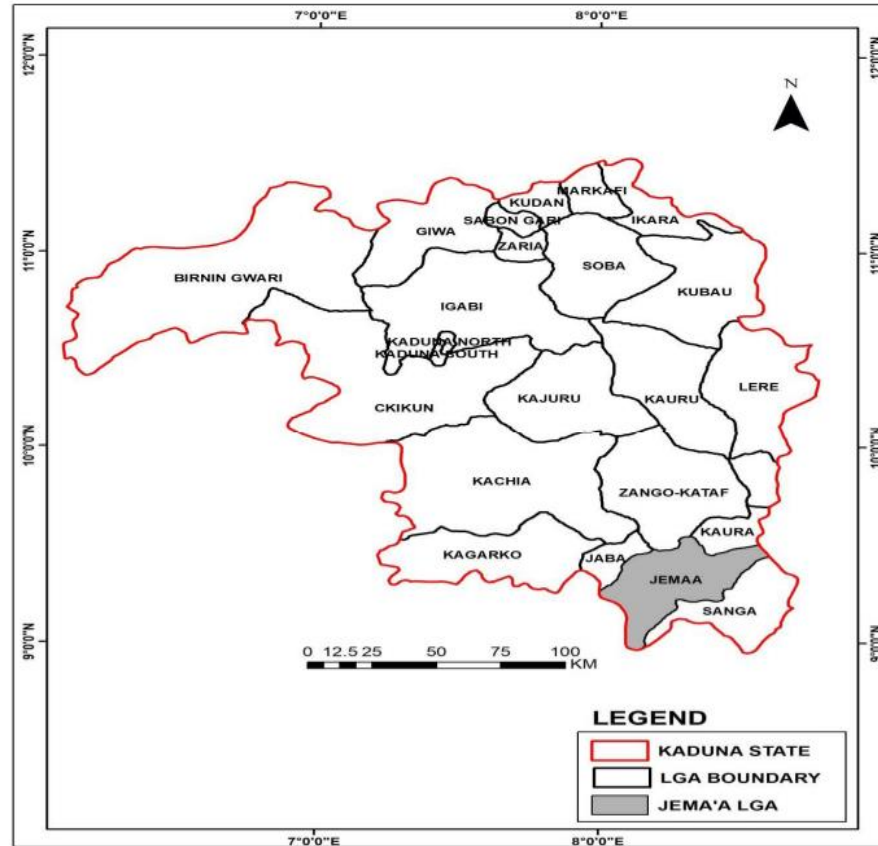


Figure 1: Kaduna State showing Jema'a Local Government Area
Source: Modified from the Administrative map of Kaduna, 2020

Methodology

We obtained annual rainfall, maximum temperature and minimum temperature data covering 1970–2025 from the Nigerian Meteorological Agency. The dataset spans 56 years, which is sufficient for detecting long-term climatic trends. We adapted the Kaduna State map from the 2020 administrative map of Kaduna State.

We conducted trend analysis to examine long-term changes in rainfall and temperature in the study area. We used the Mann–Kendall trend test to determine the presence and direction of monotonic trends in the time series, and Sen's slope estimator to estimate the magnitude of the trends.

We calculated the Mann–Kendall test statistic (S) by comparing each data point with all subsequent data points in the time series (Kendall, 1975). The statistic is expressed mathematically as:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^n \text{sgn}(X_j - X_k) \quad \dots\dots\dots \text{Eq. (1)}$$

X_j and X_k

Where: represent the sequential data values

n

is the number of observations.

The sign function is defined as:

$$\text{sgn}(x_j - x_k) = \begin{cases} +1, & \text{if } (X_j - X_k) > 0 \\ 0, & \text{if } (X_j - X_k) = 0 \\ -1, & \text{if } (X_j - X_k) < 0 \end{cases} \dots\dots\dots \text{Eq. (2)}$$

For large sample sizes ($n \geq 10$), the statistic S approximately follows a normal distribution with mean 0 (Kendall, 1975). The variance of S is computed as:

$$\text{Var}(S) = \frac{n(n-1)(2n+5)}{18} \dots\dots\dots \text{Eq. (3)}$$

The standardised test statistic (Z) is then computed to determine whether the detected trend is statistically significant (Mann, 1945; Kendall, 1975). The standardised Z value is calculated as:

$$Z = \begin{cases} \frac{S-1}{\sqrt{\text{Var}(S)}} & S > 0 \\ 0 & S = 0 \\ \frac{S+1}{\sqrt{\text{Var}(S)}} & S < 0 \end{cases} \dots\dots\dots \text{Eq. (4)}$$

At a 95% confidence level, a trend is considered statistically significant when the absolute value of Z is greater than 1.96 (Kendall, 1975).

The slope is calculated using the following expression (Sen, 1968)

$$Q_i = \frac{X_j - X_k}{j - k} \dots\dots\dots \text{Eq. (5)}$$

j and k

Where: X_j and X_k represent data values at time

j and k

represent time indices.

The statistical analysis was performed using IBM SPSS Statistics 25. In the analysis, year was treated as the independent variable, while rainfall and temperature were treated as dependent variables. The results were evaluated at the 95% confidence level.

RESULTS AND DISCUSSION

Annual Rainfall

Over the 56 years (1970 - 2025), the study area's annual rainfall shows significant year-to-year variability, with totals typically ranging from 865mm in 2007 to 2548mm in 2023 (Figure 2). At the 95% confidence level, the Mann-Kendall test shows a positive but statistically insignificant trend in rainfall ($Z = 1.28$) (Table 1). Sen's slope estimate suggested a slight increase of roughly $+5.63 \text{ mm yr}^{-1}$. The rainfall series shows significant annual variation, even though it shows no statistically significant long-term trend. While rainfall increased slightly in the 2010s and early 2020s, rainfall was lower in the early 2000s. The most extreme value in the series was recorded in 2023, driven by an extraordinarily high rainfall total. Overall, the rainfall pattern reflects high interannual variability rather than a great long-term directional change in precipitation over the study period.

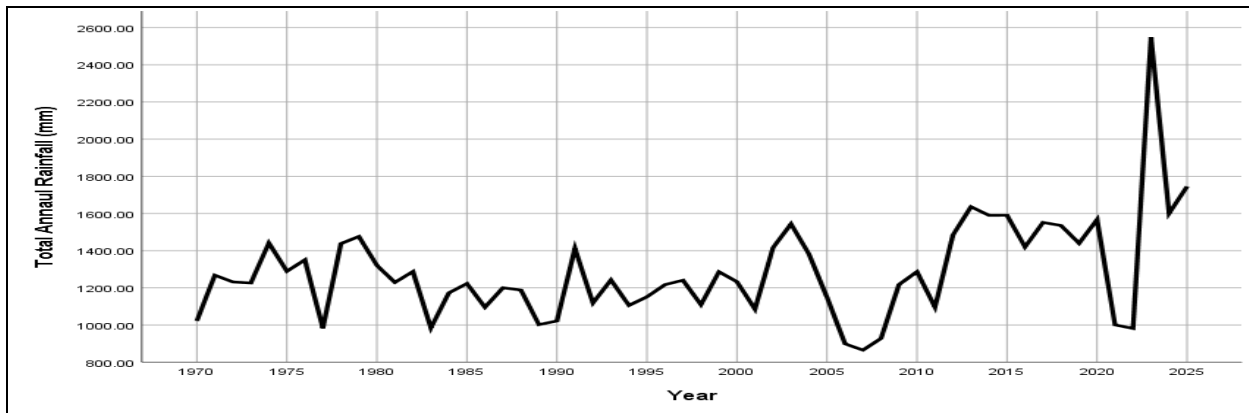


Figure 2: Total Annual Rainfall of Jema'a LGA

Source: Author's Computation based on data from the Nigerian Meteorological Agency (2025)

Maximum Annual Temperature

In the area we studied, annual maximum temperatures usually range from 27°C to 33°C . The Mann-Kendall test indicates a slight downward trend in maximum temperature ($Z = -0.67$), but this change is not statistically significant at the 95% confidence level. Furthermore, Sen's slope estimator suggests a small decrease of about -0.018°C each year over the study period (Table 1). The regression analysis yielded a coefficient of determination (R^2) of 0.191, indicating that only about 19% of the variation in maximum temperature is attributable to a long-term linear trend. The remaining variability likely reflects short-term climate fluctuations and annual differences. The spread of the data points around the regression line highlights this variability. Overall, these results indicate that daytime temperatures in Jema'a LGA have remained relatively stable from 1970 to 2025, showing no significant long-term warming or cooling trends.

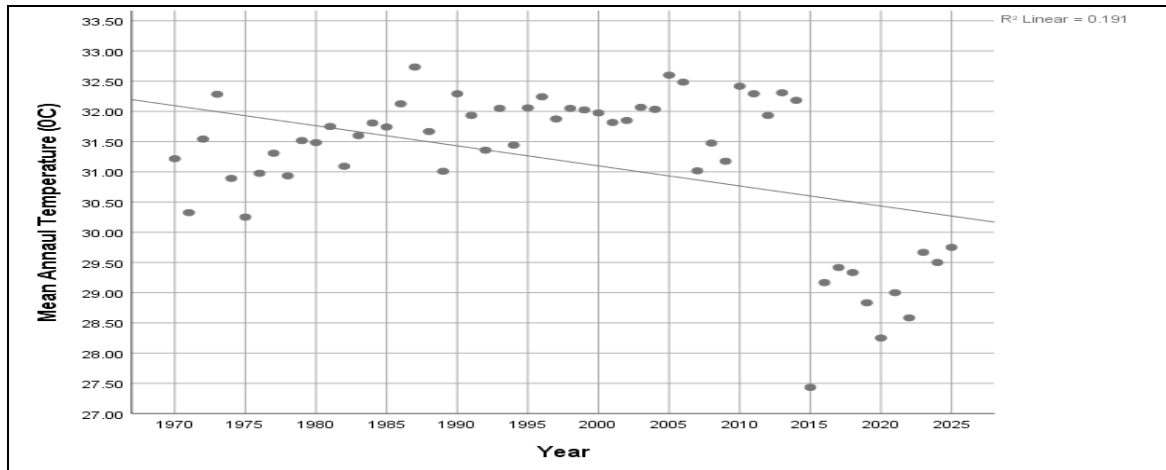


Figure 3: Maximum Annual Temperature of Jema'a LGA

Source: Author's Computation based on data from the Nigerian Meteorological Agency (2025)

Minimum Annual Temperature

In the study area, the minimum annual temperature typically ranges from 17.5 °C to 23 °C. The Mann–Kendall test indicates a significant downward trend in these minimum temperatures ($Z = -2.87$, $p = 0.005$) (Table 1 and Figure 4). Sen's slope estimator shows an average decline of about -0.051 °C per year (Table 1), indicating a slow but steady cooling of night-time temperatures from 1970 to 2025.

The regression analysis yielded a coefficient of determination (R^2) of 0.401, suggesting that roughly 40% of the variation in minimum temperature is associated with this long-term trend. Annual climate fluctuations and other environmental factors account for the remaining variation. The regression line also demonstrates a steady decrease in minimum temperatures, reinforcing the significant downward trend highlighted in the Mann–Kendall analysis. This drop in minimum annual temperatures could affect the daily temperature range, crop growth, and overall climate dynamics in the region.

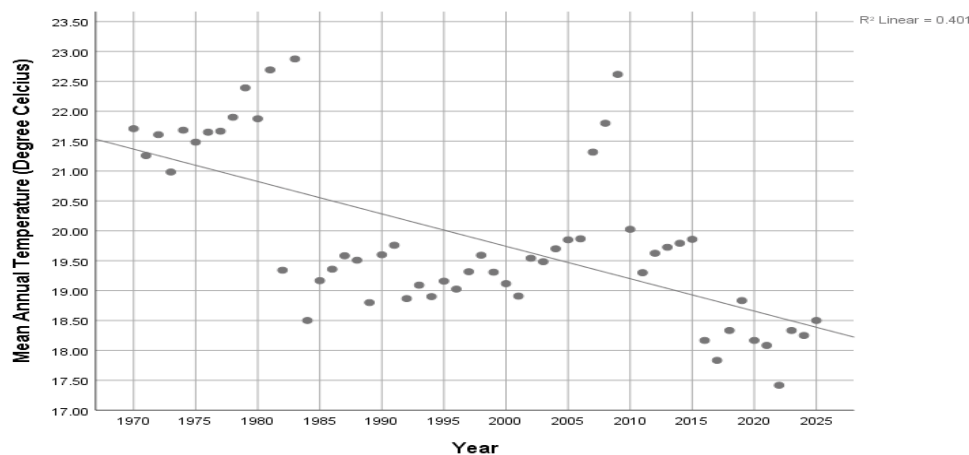


Figure 4: Minimum Annual Temperature of Jema'a LGA

Source: Author's Computation based on data from the Nigerian Meteorological Agency (2025)

Table 1: Mann–Kendall Trend Test Results for Rainfall and Temperature (1970–2025)

Variable	S	Var(S)	Z	Sen's Slope	Trend Direction	Significance
Rainfall	184	20440	1.28	+5.63 mm/year	Increasing	Not Significant
Maximum Temperature	-96	20440	-0.67	-0.018 °C/year	Decreasing	Not Significant
Minimum Temperature	-412	20440	-2.87	-0.051 °C/year	Decreasing	Significant

Source: Author's Computation based on data from the Nigerian Meteorological Agency (2025)

Decision rule:

$|Z| > 1.96 \rightarrow$ Significant trend

$|Z| \leq 1.96 \rightarrow$ Not significant

Discussion

The findings show that annual rainfall in Jema'a LGA between 1970 and 2025 shows a slight increasing trend, although the change is not statistically significant. Despite this weak upward trend, the rainfall series exhibits considerable interannual variability, with years of extremely high rainfall alternating with periods of lower rainfall. This fluctuating rainfall pattern has also been reported in several studies across Nigeria and the West African sub-region. For instance, Dennis (2024) observed that rainfall patterns in parts of Nigeria have become increasingly irregular, characterised by alternating wet and dry years rather than a consistent long-term increase or decrease. Similarly, Audu, Adamu and Garba (2026) reported strong rainfall variability in the Sahel region, noting unpredictable rainfall events and occasional extreme rainfall episodes in recent decades. The unusually high rainfall recorded in 2023 in the present study supports these observations and may reflect the increasing occurrence of extreme weather events associated with climate variability.

The analysis of maximum temperatures indicates a slight, statistically insignificant decrease, suggesting that daytime temperatures in the study area have remained relatively stable over the 56 years. This finding aligns with Dennis (2024), who reported that maximum temperature trends in some parts of Nigeria do not always show great long-term changes, but often fluctuate due to short-term climate variability. The relatively low coefficient of determination ($R^2 = 0.191$) in this study also indicates that annual climatic fluctuations and other environmental factors, rather than a persistent long-term trend, drive much of the temperature variation. However, the minimum temperature results show a statistically significant decreasing trend, indicating gradual cooling of nighttime temperatures in Jema'a LGA. This finding contrasts with many global climate studies reporting rising minimum temperatures, but it highlights that local climatic conditions can differ from global averages. (Qian, Shenhua, Zhang, & Michael, 2024). According to the Intergovernmental Panel on Climate Change (IPCC, 2021), climate change impacts often vary across regions due to local environmental conditions, land-use changes, and atmospheric circulation patterns. The consistent decline in minimum temperature observed in this study suggests that night-time cooling may be occurring in the area, which could increase the diurnal temperature range. Such changes may influence crop growth cycles, soil moisture retention and ecosystem processes, particularly in areas where agriculture is highly dependent on climatic conditions.



Overall, the results reinforce previous research showing that climate variability in Nigeria often manifests as irregular rainfall patterns and fluctuating temperatures rather than clear linear trends. The combination of high rainfall variability, stable maximum temperatures and declining minimum temperatures highlights the region's complex climate dynamics. It underscores the importance of continuous monitoring and climate-adaptation strategies for agricultural communities in Jema'a LGA.

CONCLUSION AND RECOMMENDATIONS

Annual rainfall shows a slight increasing trend; however, the trend is not statistically significant. Despite the absence of a strong long-term increase, rainfall in the study area exhibits considerable interannual variability, with alternating years of high and low rainfall. The exceptionally high rainfall recorded in recent years further suggests the growing occurrence of extreme rainfall events, which may be associated with increasing climate variability in the region.

The examination of annual maximum temperatures showed a marginal, statistically insignificant decrease, suggesting that daytime temperatures in Jema'a LGA have remained relatively stable over the study period. Conversely, minimum temperatures are decreasing significantly, suggesting a progressive cooling of nocturnal temperatures over the observed timeframe. This decline in minimum temperatures could widen the disparity between diurnal and nocturnal temperatures, influencing agricultural output, soil moisture content, and diverse ecological processes in the area.

Overall, the findings highlight that climate conditions in Jema'a LGA are characterised more by variability and fluctuations than by strong long-term trends. The combination of variable rainfall patterns, relatively stable daytime temperatures, and declining nighttime temperatures indicates complex local climate dynamics. These patterns have important implications for agriculture and rural livelihoods, emphasising the need for continuous climate monitoring and the adoption of appropriate adaptation strategies to enhance resilience among farming communities in the area.

The findings recommend disseminating climate information and early warning systems to help farmers prepare for extreme events. Encourage climate-smart agriculture, such as drought- and food-resistant crops, and support water management strategies to reduce vulnerability to erratic rainfall and increasing day-night temperature differences.

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