JOURNAL OF ENVIRONMENTAL SCIENCES AND BUILT ENVIRONMENT RESEARCH (JESBER)
2026, Vol. 1, No. 2, pp 376-386
Published by Faculty of Environmental Sciences, University of Calabar, Nigeria
Print ISSN: 3141-5547 | OPEN ACCESS

Research article

TREND OF TEMPERATURE ANOMALIES IN NORTHERN TARABA STATE FROM 1984 TO 2024: IMPLICATIONS FOR AGRICULTURE.

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ABSTRACT

Temperature variations have become an important indicator of climate change, particularly in regions where agriculture depends largely on rainfall. This study examined the trend of temperature anomalies in Northern Taraba State, Nigeria, from 1984 to 2024 and discussed their possible implications for agricultural production. Annual temperature data were obtained from the Nigerian Meteorological Agency (NiMet), Yola station, and analysed using temperature anomaly analysis, descriptive statistics, five-year grouped mean, and simple linear regression. Temperature anomalies were calculated relative to the long-term mean temperature of 365.61 °C-months (30.47°C). The results showed alternating periods of positive and negative anomalies throughout the study period, indicating the occurrence of both warmer-than-average and cooler-than-average years. However, positive anomalies became more frequent from the late 1990s onward, suggesting a gradual shift towards warmer conditions. The highest positive anomaly was recorded in 2004 (+18.6), while the most pronounced negative anomaly occurred in 1989 (−17.6). Descriptive statistics revealed a mean annual temperature of 365.61, a standard deviation of 7.83, and a coefficient of variation of 2.14 per cent, indicating relatively low year-to-year variability. The regression analysis revealed a positive trend in temperature over the study period, with an unstandardized regression coefficient of $B = 0.188$ and $R^2 = 0.083$), indicating a gradual increase in temperature over the 41-year period. The observed increase in temperature is likely to intensify evapotranspiration, reduce soil moisture, increase crop water requirements, accelerate crop maturity, and heighten heat stress, thereby reducing agricultural productivity in the predominantly rain-fed farming systems of Northern Taraba State. The study recommends strengthening climate advisory services, promoting heat-tolerant crop varieties and climate-smart agricultural practices, and expanding irrigation and sustainable land management to enhance farmers' resilience to rising temperatures.

KEYWORDS

Temperature trend temperature anomalies climate variability agriculture Northern Taraba State climate change.

INTRODUCTION

Temperature is a key climatic variable that influences agricultural productivity by regulating crop growth, evapotranspiration, soil moisture availability and the occurrence of pests and diseases. In Northern Taraba State, where farming is predominantly rain-fed, changes in temperature has significantly affect crop performance, planting calendars, and household food security. Recent studies have shown that rising temperatures associated with climate change have become one of the major environmental challenges confronting agricultural production, particularly in sub-Saharan Africa, where the adaptive capacity of smallholder farmers remains relatively low (Intergovernmental Panel on Climate Change (IPCC), 2023; Food and Agriculture Organization (FAO), 2024). Temperature anomalies are widely used to assess climate variability because they indicate departures of observed temperatures from the long-term average. Positive anomalies represent warmer-than-average years, whereas negative anomalies indicate relatively cooler conditions. The analysis of these anomalies provides a better understanding of long-term climatic behaviour than annual temperature values alone, as it highlights periods of sustained warming or cooling, the frequency of extreme temperature events, and changes in climatic patterns over time (World Meteorological Organization [WMO], 2023). Assessing temperature anomalies over the period 1984–2024 is important for understanding the extent of climate fluctuations in Northern Taraba State and their implications for agricultural production. Persistent increases in temperature can accelerate evapotranspiration, reduce soil moisture reserves, increase crop water requirements, shorten crop growth duration, and expose crops to heat stress, ultimately leading to lower yields and increased production risks. Conversely, cooler-than-average years may alter crop development and seasonal productivity depending on the prevailing environmental conditions and crop species. Understanding these long-term temperature variations therefore provides valuable information for evaluating farmers' vulnerability and designing appropriate climate adaptation strategies. This section examines the trend of annual temperature anomalies in Northern Taraba State over the 41-year period (1984–2024). The analysis employs temperature anomaly assessment, descriptive statistics, five-year running mean, and simple linear regression to determine the nature and direction of temperature changes. The findings provide empirical evidence on the changing thermal conditions of the study area and their implications for agricultural productivity, climate resilience, and sustainable farming in Northern Taraba State.

LITERATURE REVIEW

Ishaku, Umaru, Adebayo, Löwner, and Okhimamhe (2024) conducted a comprehensive assessment of long-term rainfall and temperature trends in North-Eastern Nigeria to evaluate the extent of climate variability across the region. The study analysed monthly rainfall, maximum temperature, and minimum temperature data obtained from NASA's Prediction of Worldwide Energy Resources (POWER) database for the period 1981–2021, covering nine meteorological stations and fifty-nine observation points. The researchers employed the non-parametric Mann–Kendall (MK) trend test to determine the direction and significance of climatic trends, while the Theil–Sen slope estimator was used to quantify the magnitude of change. In addition, Inverse Distance Weighting (IDW) interpolation was applied to produce spatial representations of rainfall and temperature patterns across the study area. Maximum temperature exhibited a statistically significant increasing trend across all stations, while minimum temperature showed a slight but statistically insignificant decline. Spatial analysis further confirmed an overall decrease in rainfall, accompanied by a modest increase in maximum temperature and a marginal decline in minimum temperature. Based on these findings, the authors emphasized the need for proactive dissemination of climate information to strengthen climate resilience and support informed decision-making in North-Eastern Nigeria. One of the major strengths of this study is its extensive spatial coverage, involving nine meteorological stations and fifty-nine observation points distributed across North-Eastern Nigeria, which provides a comprehensive regional perspective of climate variability. The use of a 41-year climatic dataset also enhances the reliability of the observed trends. Furthermore, the integration of robust statistical techniques, including the Mann–Kendall test, Theil–Sen slope estimator, and Inverse Distance Weighting interpolation, improved the accuracy of trend detection and enabled the visualization of spatial climatic patterns. These methodological approaches strengthen the credibility of the findings and provide valuable information for climate planning and policy formulation. Despite these strengths, the study has some limitations. It concentrated primarily on temperature trends without considering other important climatic variables such as relative humidity, which significantly influences crop growth and agricultural productivity. The research also focused on climatic trend analysis without empirically examining the implications of these changes for agricultural production, farmers' vulnerability, or adaptation strategies. Additionally, the reliance on satellite-derived NASA POWER data, although widely accepted, may not fully capture localized climatic variations that could be detected using ground-based meteorological observations. The study therefore leaves an important research gap by not assessing how the observed climatic trends influence agricultural systems and the livelihoods of farming communities.

Bello, Msheliza, and Nyikun (2023) investigated the anomalies and trends of rainfall and temperature in Maiduguri, Borno State, Nigeria, using climatic records obtained from the Nigerian Meteorological Agency (NiMet) for the period 1974–2014. The study employed descriptive statistics, normality tests, the Rainfall Anomaly Index (RAI), the Standardized Anomaly Index (SAI), and linear time series analysis to examine the temporal behaviour of rainfall and temperature. The findings revealed that the rainfall anomaly index reflected predominantly humid conditions, with positive anomalies occurring more frequently than negative anomalies for both rainfall and temperature. Annual rainfall and mean temperature exhibited increasing trends at rates of 0.0361 mm year^{-1} and 0.0248°C year, respectively. The analysis further showed no significant difference between maximum and minimum temperatures. Seasonally, the highest temperatures occurred between April and May, while peak rainfall was concentrated between June and August. Monthly rainfall trends indicated increasing rainfall in almost all months except April, which recorded a declining trend of −0.25 mm year. Based on these findings, the authors recommended the adoption of flood management strategies and urban tree planting to mitigate the effects of increasing rainfall and rising temperatures. The major strength of this study lies in its use of a relatively long climatic record spanning 41 years, which enhances the reliability of the detected trends. The application of anomaly indices alongside trend analysis also provided a comprehensive understanding of climatic variability beyond simple averages, thereby improving the interpretation of long-term changes in rainfall and temperature patterns. Furthermore, the study generated useful evidence for climate adaptation planning in the semi-arid environment of northeastern Nigeria. Despite these strengths, the study has notable limitations. It focused exclusively on climatic variables without examining how the observed anomalies affect agricultural production, farmers' livelihoods, or adaptation responses. The analysis was also geographically limited to Maiduguri, making it difficult to generalize the findings to other ecological zones with different climatic characteristics. In addition, the study relied primarily on descriptive and trend analyses without assessing the statistical relationship between climatic anomalies and socioeconomic or agricultural outcomes. The study therefore leaves an important research gap by not investigating the implications of rainfall and temperature anomalies for agricultural productivity and farmers' vulnerability. It also did not consider relative humidity as an important climatic parameter influencing crop growth and moisture availability.

Eyefia (2025) investigated the trend and spatial variations of Annual Temperature Range (ATR) across Nigeria with the aim of understanding regional differences in temperature variability and their implications for climate change adaptation. The study utilized maximum and minimum temperature data obtained from the NASA Prediction of Worldwide Energy Resources (POWER) database. Annual Temperature Range was computed from the differences between monthly mean maximum and minimum temperatures using Microsoft Excel. The data were analysed using descriptive statistics, inferential statistics, linear regression, the non-parametric Mann–Kendall trend test, and spatial analysis techniques to examine temporal and geographical variations in ATR across the country. The findings revealed marked spatial differences in annual temperature range, with northern states such as Kano (33.9°C), Jigawa (33.7°C), and Borno (33.2°C) recording the highest ATR values, while southern coastal states including Lagos (12°C) and Rivers (18°C) exhibited much lower values due to the moderating influence of the Atlantic Ocean. The trend analysis further showed statistically significant increases in annual temperature range in eleven states, particularly in the northern and central parts of Nigeria, indicating a warming climate. The study concluded that urbanization and prevailing meteorological conditions play important roles in shaping regional temperature variations and recommended the adoption of region-specific climate adaptation strategies to mitigate the impacts of increasing temperature fluctuations. One of the major strengths of this study is its national coverage, which provides a comprehensive assessment of the spatial distribution of annual temperature range across Nigeria. The combination of descriptive and inferential statistics with the Mann–Kendall trend test and spatial analysis enhanced the robustness of the findings by identifying both temporal and geographical patterns of temperature variability. The use of NASA POWER data also ensured extensive spatial coverage, particularly in areas with limited ground-based meteorological observations. Furthermore, the study provides valuable evidence for policymakers by demonstrating that temperature variability differs considerably across ecological zones, thereby emphasizing the need for location-specific climate adaptation measures. Despite these strengths, the study has several limitations. It focused exclusively on annual temperature range without incorporating other important climatic variables such as rainfall and relative humidity, which jointly influence agricultural productivity and environmental conditions. The analysis also did not examine the implications of increasing annual temperature range for crop production, farmers' livelihoods, or agricultural adaptation. In addition, although the study identified significant regional differences in temperature variability, it did not assess climatic anomalies or investigate the vulnerability of farming communities to the observed climatic changes.

METHODOLOGY

Study Area

Northern Taraba State is located in Taraba State which is located in northeastern region of Nigeria and lies within the Northern Guinea Savannah ecological zone. Geographically, the area extends approximately between latitudes 8°30′N and 10°30′N of the Equator and longitudes 9°00′E and 11°45′E of the Greenwich Meridian. Northern Taraba State is bounded to the north by Bauchi State and Gombe State, to the west by Plateau State and Nasarawa State, to the east by Adamawa State, and to the south by the central and southern parts of Taraba State. The study area comprises major of the Northern Zone of the state which local government areas include Jalingo, Ardo-Kola, Lau, and Karim Lamido. Jalingo serves as the administrative headquarters and commercial center of the state, while the surrounding LGAs are predominantly rural and agrarian. Agriculture is the major occupation of the people, employing a large proportion of the population. Farmers in the area cultivate crops such as maize, rice, millet, beans, sorghum, yam, cassava, groundnut, and vegetables, while livestock rearing and fishing are also practiced, especially in riverine communities. The availability of fertile floodplains and alluvial soils along river valleys supports extensive farming activities in many parts of the region (Taraba State Government, 2022).

Temperature data from 1984 to 2024 (41 years) were obtained from the Nigerian Meteorological Agency (NiMet) Yola meteorological station, located approximately at 9.23^0 N and 12.47^0 E. Annual temperature values were derived by summing the twelve-monthly mean temperatures for each year. Annual mean temperature was subsequently obtained by dividing the annual total by twelve. Monthly mean temperature records were used to derive annual mean temperature values, which were subsequently subjected to anomaly analysis, descriptive statistics, five-year grouped mean and linear regression analysis to determine the temporal pattern of temperature over the study period. Accordingly, the linear trend lines were plotted for the annual temperature data using Microsoft Excel statistical tool, and estimation of changes in temperature was determined. The simple linear regression model is expressed as:

$$Y = \beta_0 + \beta_1 X + \mathcal{E}$$

Where:

Y= dependent variable (Temperature)

X = independent variable (year)

β_0 = intercept (value of Y when X = 0)

β_1 = rate at which crop yield changes due to changes in temperature slope

Ɛ = random error term accounting for other factors not included in the model.
The dataset was examined for completeness, missing observations, duplicate records, inconsistent units and anomalous values before analysis. Monthly observations were aggregated to obtain annual climatic values, which were subsequently used to calculate anomalies, descriptive statistics and five-year running means. Missing observations were identified and excluded from calculations where reliable replacement values were unavailable; no zero values were assigned to missing records. Since the study relied on a single long-term meteorological station, spatial interpolation or homogenization across the five LGAs was not undertaken. Instead, the Yola station series was used as a regional climatic reference for the selected LGAs. The validated climatic series was then subjected to trend and variability analyses. The five selected LGAs are Lau, Jalingo, Ardo-Kola, Karim Lamido and Zing were used for the spatial assessment of farmers and agricultural conditions, while the common meteorological series represented the broader climatic conditions of the study area.

Temperature anomalies were calculated as the difference between the annual temperature value for a given year and the long-term mean temperature for the reference period 1984–2024. The anomaly was computed using the formula:
where:
TA = Temperature anomaly for year *i*;
T_i = Annual temperature value for year *i*;
T = Long-term mean temperature for the reference period (1984–2024).
The long-term mean temperature for the study period was 365.61°C-months (equivalent to 30.47°C when expressed as annual mean temperature). Positive anomaly values indicate years that were warmer than the 1984–2024 average, while negative anomaly values indicate years that were cooler than the long-term average.

The observed warming has important implications for agriculture because higher temperatures increase evapotranspiration, reduce soil moisture availability, accelerate crop water loss, and expose crops to greater heat stress. In a predominantly rain-fed agricultural system such as Northern Taraba State, these conditions are likely to reduce crop productivity, increase pest and disease incidence, and heighten farmers' vulnerability to climate fluctuations. The findings therefore underscore the need for climate-smart agricultural practices, improved climate information services, and the development of heat-tolerant crop varieties to strengthen the resilience of farming systems against the effects of rising temperatures (FAO, 2024; IPCC, 2023).

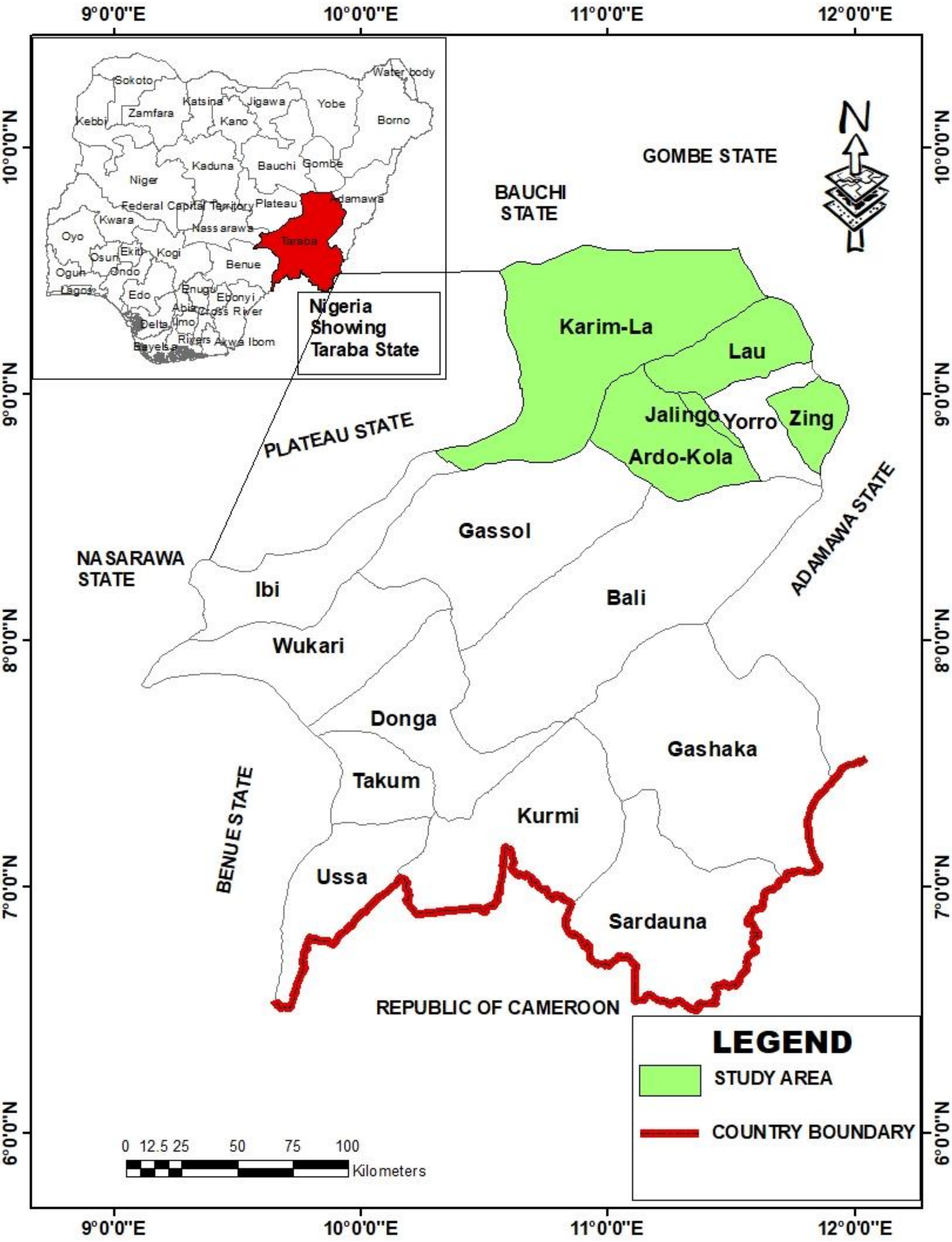

Figure 1: Taraba State Map showing the study areas.

***Source**: Geographical Information Systems Unit, Department of Geography and Environmental Sciences, University of Calabar, 2025.*

RESULTS AND DISCUSSION

Trend of Temperature Anomalies from 1984 to 2024.

The results indicate a gradual warming trend, characterized by a transition from predominantly negative temperature anomalies in the 1980s and early 1990s to more frequent positive anomalies from the late 1990s onwards. Although annual temperatures fluctuated from year to year, the increasing occurrence of warmer-than-average years suggests a sustained rise in temperature over the study period. This pattern is consistent with recent reports that identify increasing temperatures as one of the most evident indicators of climate change across Africa

(IPCC, 2023; WMO, 2023). The descriptive statistics showed a mean annual temperature of 365.61, a standard deviation of 7.83, and a coefficient of variation of 2.14 per cent. Although the temperature anomaly analysis revealed alternating warm and cool years throughout the study period, the coefficient of variation (2.14%) indicates that annual temperatures exhibited low relative variability around the long-term mean. This suggests that temperature conditions were generally stable despite the occurrence of notable positive and negative anomalies in some years. Therefore, the observed fluctuations reflect interannual departures from the mean rather than extreme temperature instability. The significant positive trend observed over the study period indicates that the more important climatic characteristic is the gradual warming pattern rather than high year-to-year variability. The five-year running mean further demonstrated that temperatures remained fairly stable during the early years but increased steadily from the late 1990s onwards, while the simple linear regression confirmed a statistically significant positive relationship between time and annual temperature ($\beta = 0.188$; $R^2 = 0.083$). These findings indicate that Northern Taraba State has experienced measurable climatic warming over the past four decades, a trend that agrees with observations reported for northern Nigeria and other parts of West Africa (Ayanlade, Radeny, & Morton, 2022; NiMet, 2024).

Table 1 presented temperature values which represent the annual sum of the twelve-monthly mean temperatures obtained from NiMet records. The unit was as degree-months (°C-months) or annual cumulative temperature (°C). To obtain the annual mean temperature in degrees Celsius, each annual value was divided by 12. The anomaly series was referenced to the 1984–2024 climatological baseline, meaning that all departures were measured relative to the average temperature conditions of the entire 41-year study period. Positive anomalies therefore represent warmer-than-average years, whereas negative anomalies represent cooler-than-average years. The increasing frequency of positive anomalies after the late 1990s provides evidence of progressive warming in Northern Taraba State. This warming trend has important agricultural implications because higher temperatures can increase evapotranspiration, reduce soil moisture availability, raise crop water requirements, and intensify heat stress, thereby affecting crop productivity in the predominantly rain-fed farming systems of the area. See Figure 2.

Table 1: Annual Sum of the Monthly Mean Temperatures

1984	362.8	-2.8
1985	359.3	-6.3
1986	362.0	-3.6
1987	365.2	-0.4
1988	357.9	-7.7
1989	348.0	-17.6
1990	367.4	1.8
1991	366.2	0.6
1992	356.7	-8.9
1993	359.3	-6.3
1994	354.5	-11.2
1995	356.5	-9.1
1996	355.5	-10.1
1997	354.1	-11.6
1998	368.9	3.3
1999	374.2	8.6
2000	374.0	8.4
2001	368.7	3.1
2002	376.8	11.2
2003	376.4	10.8
2004	384.2	18.6
2005	376.3	10.7
2006	378.8	13.2
2007	372.5	6.8
2008	365.5	-0.1
2009	369.0	3.4
2010	371.6	6.0
2011	362.8	-2.8
2012	359.4	-6.2
2013	364.7	-1.0
2014	360.6	-5.0

2015	364.5	-1.1
2016	362.9	-2.7
2017	367.7	2.0
2018	365.9	0.3
2019	368.7	3.1
2020	366.5	0.9
2021	364.2	-1.4
2022	354.5	-11.2
2023	373.4	7.8
2024	372.1	6.4

Source: NiMet Yola, 2025.

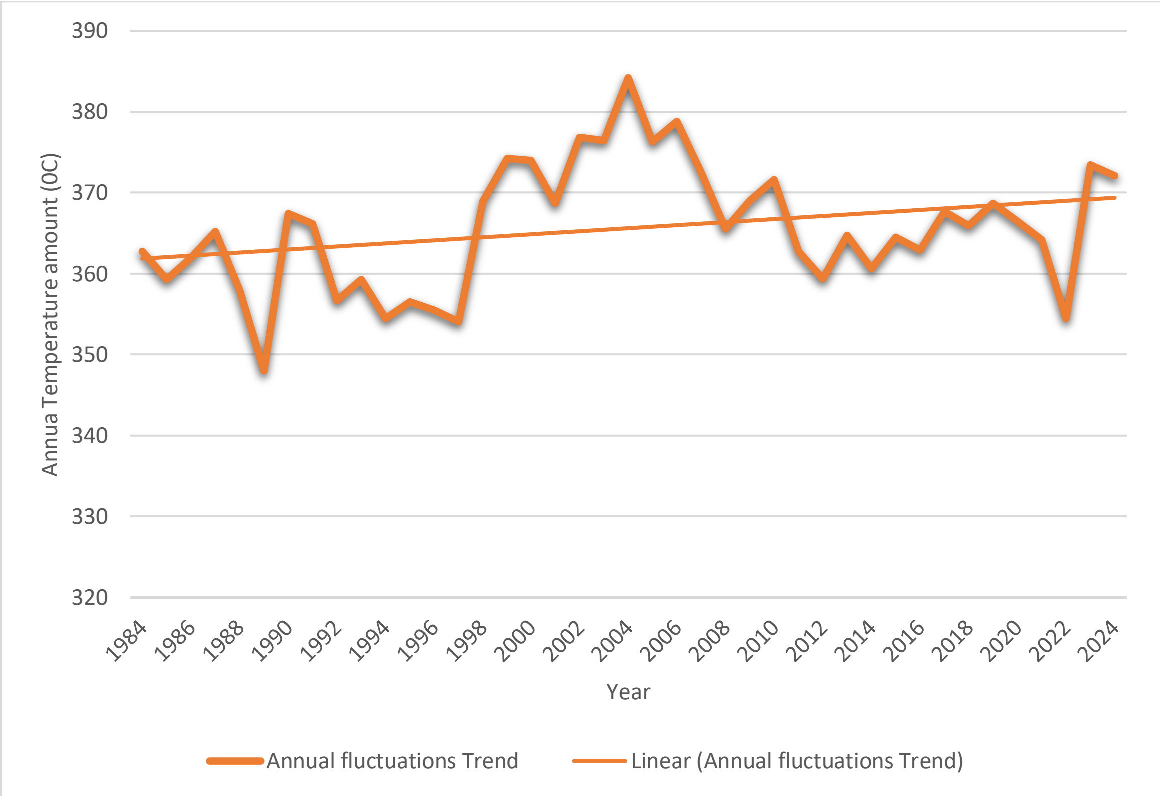

Figure 2: Annual temperature fluctuations from 1984 to 2024

Source: Researcher's Analysis, 2025.

Table 2: Regression Statistics Results for Annual Temperature Trend in Northern Taraba State (1984–2024).

Constant	-10.921	200.939	–	-0.054	0.957	-417.357to 395.516
Year	0.188	0.100	0.287	1.874	0.068	-0.015 to 0.391

Source: *Computed by the Authors from NiMet Annual Mean Temperature Data (1984–2024) using Ordinary Least Squares (OLS) Regression in SPSS.*

Table 3: Model Statistics

R	0.287
R²	0.083
Adjusted R²	0.059
Standard Error of Estimate	7.597
F-statistic	3.512
Degrees of Freedom	(1, 39)

Sample Size (n)	41
Significance Level	p = 0.068

Source: *Researcher's Analysis of NiMet Temperature Data (1984–2024)*

Table 2 and 3 shows the regression analysis revealed a positive trend in temperature over the study period, with an unstandardized regression coefficient of B = 0.188 and $R^2 = 0.083$), indicating a gradual increase in temperature over the 41-year period. The slope coefficient (b = 0.188, SE = 0.100) suggests that temperature increased gradually over time. However, the trend was not statistically significant at the 5% level (t = 1.874, p = 0.068). Furthermore, the 95% confidence interval (-0.015 to 0.391) includes zero, indicating that the observed warming trend cannot be distinguished from no trend at the 95% confidence level. The model explains only 8.3% of the variation in annual temperature ($R^2 = 0.083$), implying that other climatic and environmental factors contributed substantially to temperature variability.

Implications of positive and negative temperature anomalies from 1984 to 2024.

Figure 3 shows alternating warm and cool years relative to the long-term mean. The result reveals these anomalies which provided useful insight into periods of heat stress and periods of relatively cooler conditions that influence crop performance across farming communities.

Negative anomalies dominate much of the period from 1984 to the mid-1990s and again around 2011–2016, showing that several years were cooler than the long-term average. Some of the lowest departures include 1989 (–17.6), 1994 (–11.2), 1997 (–11.6), and 2022 (–11.2). These represent years with distinctly cooler conditions. Moderate negative departures such as 1985 (–6.3), 1992 (–8.9), 2012 (–6.2), and 2014 (–5.0) indicate mild cool phases.

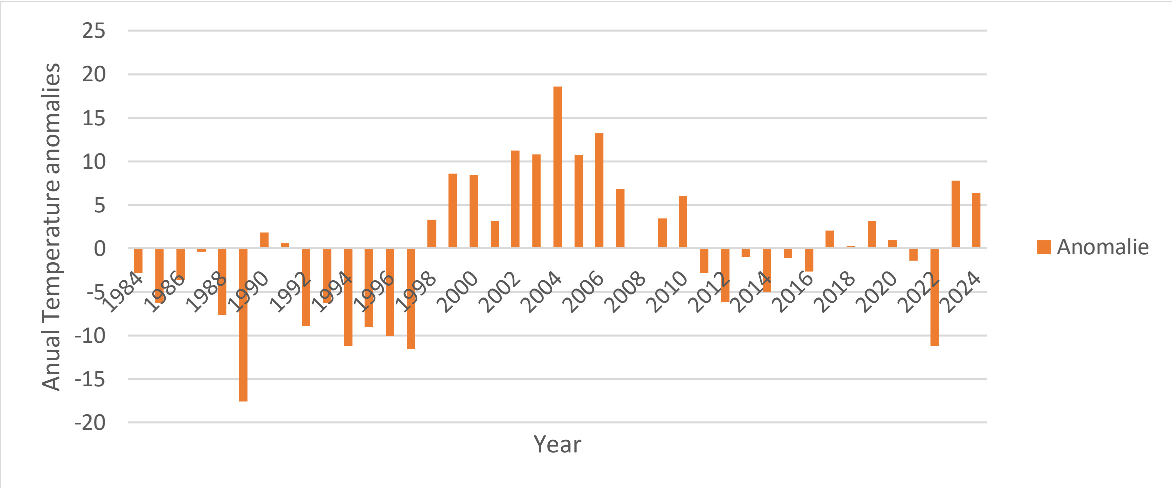

Figure 3: Annual temperature anomalies from 1984 to 2024

Source: Researcher's Analysis, 2025.

Mean, Standard Deviation and Coefficient of Variation for Annual Temperature from 1984 to 2024 (41) years.

Table 4, shows the mean, standard deviation and coefficient of variation values for annual temperature from 1984 to 2024 (41 years). From the results, the mean is 365.61, and a standard deviation of 7.83 for annual temperature in Northern Taraba State. The standard deviation result indicates considerable temperature fluctuations over time. Since agriculture in the region is mainly rain-fed, such variability can negatively affect farming activities and crop production. Crops such as millet, sorghum, maize, rice, and groundnut depend on suitable temperature conditions for proper growth and development. A coefficient of variation of 2.14 per cent for annual temperature in Taraba State indicates that temperature conditions vary only slightly around the average. This suggests that annual temperatures are relatively stable over time, creating more predictable climatic conditions for farming activities. Such stability can help farmers plan planting and harvesting periods more effectively and improve overall farm management practices.

Table 4: Mean, Standard Deviation and Coefficient of Variation for Temperature from 1984 to 2024.

Mean	365.61

Standard deviation	7.83
Coefficient variation	2.14

Source: Researcher's Analysis, 2025.

Table 3 and Figure 4, shows the "five-year grouped mean". In addition, five-year grouped mean was recalculated using successive overlapping five-year windows (e.g., 1984–1988, 1985–1989, 1986–1990, etc.), ensuring that each mean reflects a continuously shifting five-year period. Figure 4 has been reconstructed using the corrected moving mean series, providing a more accurate representation of long-term temperature variability and trend patterns.

Table 3: Five-Year Grouped Mean for Temperature

1984	362.8	361.44
1985	359.3	361.44
1986	362	361.44
1987	365.2	361.44
1988	357.9	361.44
1989	348	359.52
1990	367.4	359.52
1991	366.2	359.52
1992	356.7	359.52
1993	359.3	359.52
1994	354.5	357.9
1995	356.5	357.9
1996	355.5	357.9
1997	354.1	357.9
1998	368.9	357.9
1999	374.2	374.02
2000	374	374.02
2001	368.7	374.02
2002	376.8	374.02
2003	376.4	374.02
2004	384.2	375.46
2005	376.3	375.46
2006	378.8	375.46
2007	372.5	375.46
2008	365.5	375.46
2009	369	365.5
2010	371.6	365.5
2011	362.8	365.5
2012	359.4	365.5
2013	364.7	365.5
2014	360.6	364.32
2015	364.5	364.32
2016	362.9	364.32
2017	367.7	364.32
2018	365.9	364.32
2019	368.7	366.57
2020	366.5	366.57
2021	364.2	366.57
2022	354.5	366.57
2023	373.4	366.57
2024	372.1	366.57

Source: Researcher's Analysis, 2025.

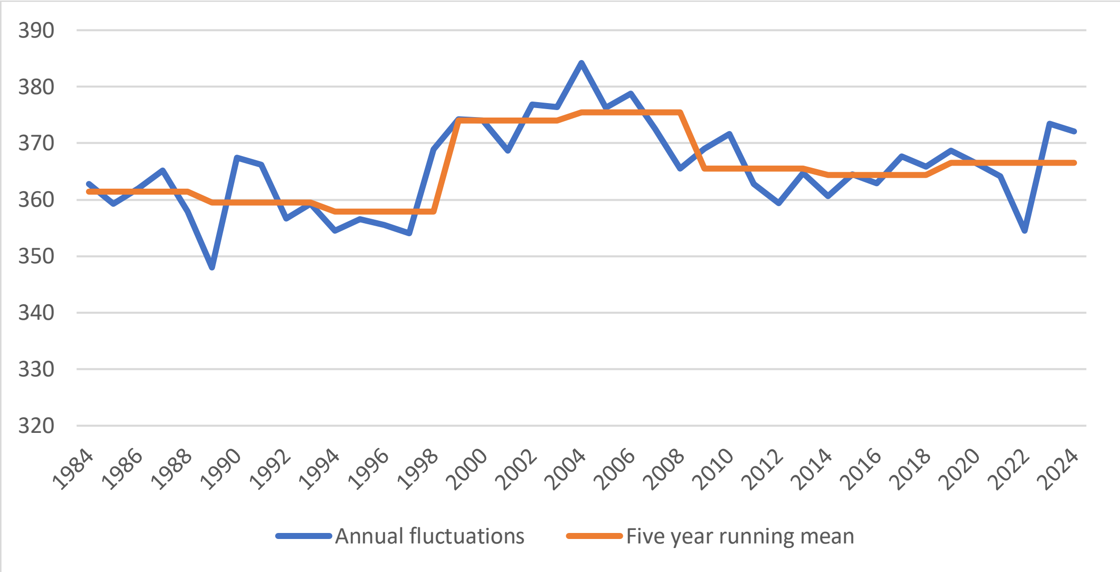

Figure 4: Five years Grouped Mean Temperature from 1984 to 2024.

Source: Researcher's Analysis, 2025.

Implications of Positive and Negative Temperature Anomalies on Agriculture from 1984 to 2024.

The findings of this study show that Northern Taraba State experienced a gradual increase in temperature between 1984 and 2024, despite yearly fluctuations. The warming trend is reflected in the increasing occurrence of positive temperature anomalies from the late 1990s and supported by the positive regression coefficient ($\beta = 0.188$). This indicates a progressive change in the thermal condition of the area, with important implications for agriculture. Since crop growth depends on suitable temperature conditions for processes such as germination, photosynthesis, flowering, and grain filling, the increasing frequency of warmer years suggests greater exposure of crops to heat stress and possible reductions in yield performance.

The transition from cooler conditions in the 1980s and early 1990s to warmer conditions in subsequent decades, particularly the high positive anomalies recorded between 1999 and 2007, indicates a sustained warming pattern rather than isolated temperature increases. These warmer conditions likely enhanced evapotranspiration, accelerated soil moisture depletion, and increased crop water requirements, especially under the rain-fed farming system predominant in Northern Taraba State. Although the coefficient of variation (2.14%) indicates relatively low annual temperature variability, the continuous rise in temperature remains significant because persistent warming can shorten crop development periods, reduce grain-filling duration, and negatively affect the productivity of crops such as maize, rice, sorghum, millet, and groundnut.

Increasing temperature may have implications for soil moisture conditions, pest and disease dynamics, and agricultural management in Northern Taraba State. According to previous studies, higher temperatures can increase evapotranspiration rates and soil moisture loss, potentially reducing water availability for crops, particularly during periods of limited rainfall. Such conditions may contribute to moisture stress and reduced crop performance if they occur during sensitive growth stages. However, the effects of temperature anomalies are not uniform across crops, seasons, or production systems. Moderate positive temperature anomalies may enhance crop growth and development where temperatures remain within optimal thresholds, whereas excessive warming can increase heat and moisture stress. Similarly, negative temperature anomalies may reduce heat stress and conserve soil moisture in some situations but could also slow crop development and delay maturation depending on the crop type and growth stage. In addition, warmer conditions have been associated in the literature with changes in the distribution, survival, and activity of certain pests and pathogens, although such effects were not directly assessed in this study. Therefore, these agricultural outcomes should be regarded as potential implications of the observed temperature anomalies rather than direct effects demonstrated by the present analysis. The corrected five-year moving mean indicates that the observed warming pattern reflects a persistent long-term climatic trend, which may influence agricultural conditions in the study area over time when combined with other environmental and management factors.

The regression analysis ($R^2 = 0.083$) confirms a positive warming trend, although temperature changes are influenced by several climatic and environmental factors. The findings agree with previous studies that reported increasing temperatures across Nigeria and sub-Saharan Africa and their negative implications for agricultural systems. The observed warming trend in Northern Taraba State highlights the need for improved adaptation measures, including the adoption of heat-tolerant crop varieties, expansion of irrigation facilities, soil moisture conservation practices, adjustment of planting dates, and improved access to climate information. These strategies are essential for strengthening farmers' resilience and sustaining agricultural production under changing climatic conditions.

CONCLUSION

In conclusion, the analysis of annual temperature records for Northern Taraba State from 1984 to 2024 indicates a gradual and statistically significant increase in temperature over the study period. Although year-to-year fluctuations were observed, the trend points to sustained warming, particularly from the late 1990s onwards. This is supported by the increasing occurrence of positive temperature anomalies, the upward trend in the five-year running mean, and the positive regression coefficient, all of which confirm that temperatures have risen progressively over the past four decades. The anomaly analysis further shows a shift from predominantly negative temperature anomalies in the 1980s and early 1990s to more frequent positive anomalies in the subsequent years, indicating a transition from relatively cooler to warmer climatic conditions. The descriptive statistics, with a mean annual temperature of 365.61, a standard deviation of 7.83, and a coefficient of variation of 2.14 per cent, suggest that although annual temperature variability remained relatively low, the long-term warming trend was consistent. The regression analysis also confirmed that the increase in temperature was statistically significant, leading to the rejection of the null hypothesis of no significant change in temperature over the study period. The warming trend has important implications for agriculture in Northern Taraba State. Higher temperatures are likely to increase evapotranspiration, reduce soil moisture availability, shorten crop growth periods, and expose crops to greater heat stress, thereby affecting crop productivity. Given that agriculture in the area is largely rain-fed, continued increases in temperature are likely to heighten farmers' vulnerability to climate fluctuations and underscore the need for effective climate adaptation measures to sustain agricultural production.

DECLARATIONS

Ethical approval: Not applicable. The study used secondary annual temperature data and did not involve human participants or animals.
Informed consent: Not applicable.
Funding: No external funding was reported for the study.
Conflict of interest: The authors declare no conflict of interest.
Data availability: The temperature data used in the study were obtained from the Nigerian Meteorological Agency (NiMet), Yola station. Supporting data may be made available by the corresponding author upon reasonable request, subject to the data provider's conditions.
Author contributions: All authors contributed to the conceptualisation, methodology, analysis, interpretation and preparation of the manuscript, and all authors read and approved the final manuscript.
Acknowledgements: The authors acknowledge the Nigerian Meteorological Agency (NiMet), Yola station, for providing the temperature data used in the study.

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