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SPATIO-TEMPORAL ANALYSIS OF EXTREME HEAT WAVE EVENTS IN GOMBE STATE, NIGERIA

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ABSTRACT
This paper presents a comprehensive spatio-temporal analysis of extreme heatwave events in Gombe State, Nigeria, with a focus on four selected Local Government Areas (LGAs): Gombe, Akko, Yamaltu-Deba, and Kwami. Drawing on historical climate data spanning 1970–2024 from WorldClim and CRU TS datasets, alongside recent weather observations (2022–2026), the study examines temperature trends, as well as the frequency, intensity, and spatial distribution of heatwave events across the region. The results reveal a statistically significant warming trend of +0.18°C per decade ($R^2 = 0.385$), with more accelerated warming observed after the year 2000. Seasonally, March and April are identified as the most critical heatwave months, during which maximum temperatures reach as high as 43°C (109°F). Spatial analysis further shows clear intra-state variability, with urbanized LGAs—particularly Gombe and Akko—experiencing higher heatwave intensity due to urban heat island effects. In contrast, rural LGAs exhibit comparatively lower but still increasing heat exposure. Overall, the findings provide robust, localized evidence of intensifying heat extremes in the Sudano-Sahelian region and underscore the urgent need for targeted climate adaptation strategies and public health interventions.

Keywords: Heatwaves, spatio-temporal, climate change, extreme heat events

INTRODUCTION

Climate change has become one of the principal factors responsible for the increasing occurrence, severity, and persistence of extreme weather events across the globe. In Nigeria, its impacts are particularly pronounced in the North-Eastern region, where geographical proximity to the Sahara Desert and heavy reliance on climate-dependent livelihoods make communities especially vulnerable (Agada & Yakubu, 2022; Adejuwon, 2022). Within this region, heatwaves have emerged as an important but often underestimated climate-related hazard. Heatwaves are commonly described as periods of abnormally high temperatures lasting at least three consecutive days (Agu et al., 2020; Akatah et al., 2025). More specifically, they occur when daily maximum temperatures exceed the 90th or 95th percentile of the local climatic baseline for three or more successive days (Perkins & Alexander, 2013).

Unlike floods or droughts, heatwaves often develop gradually and therefore receive less public attention, despite their significant consequences. They are frequently referred to as “silent disasters” because of their substantial impacts on human health, mortality, and economic productivity (Agada & Yakubu, 2022). These effects are particularly severe in the Sahel, one of the world’s most climate-sensitive regions (IPCC, 2022; WMO, 2021). Northeastern Nigeria lies within this vulnerable zone and has experienced considerable climatic changes over recent decades. Gombe State, located within the Savanna–Sahel transitional belt, has recorded a noticeable increase in extreme heat events as a result of both global climate change and local human-induced environmental modifications (Agada & Yakubu, 2022; Ikusemoran et al., 2023). Consequently, there is an urgent need for detailed investigations into the spatial and temporal characteristics of heatwaves at the Local Government Area (LGA) level, particularly in LGAs such as Akko and Gombe, to support the formulation of effective heat-response and adaptation strategies.

The effects of increasing temperatures are extensive and affect multiple sectors. High temperatures have been associated with heat stress, dehydration, cardiovascular disorders, and other heat-related illnesses, with children, older adults, and economically disadvantaged populations being the most susceptible (Audu et al., 2022; Ishaku et al., 2024). Furthermore, heatwaves frequently coincide with other climate extremes, particularly droughts, thereby amplifying their cumulative impacts. This interaction was clearly demonstrated between 2010 and 2014, when simultaneous heatwave and drought events significantly reduced water availability and agricultural productivity across the region (Agada & Yakubu, 2022).

Recent observations indicate that extreme heat events have become more frequent and intense throughout West Africa, posing serious challenges to public health, agriculture, water security, and economic development. In Gombe State, where livelihoods depend largely on rain-fed farming and outdoor informal occupations, these impacts are particularly significant. Climatic analyses provide evidence of this warming trend, with positive Kendall's Z statistics of 4.38 and 4.43 for maximum and mean temperatures, respectively, indicating statistically significant upward trends ($p < 0.05$) (Alhaji et al., 2018). Likewise, studies conducted across Nigeria have reported increasing occurrences of hot extremes together with declining cold extremes, particularly within the Sahel and Guinea ecological zones (Abatan et al., 2015).

At the regional level, evidence suggests that the Sahel is warming at a rate exceeding the global average. Since the 1970s, average temperatures across West Africa have risen by approximately 0.5–1.0°C. In comparison, climate projections estimate a further increase of between 2.0°C and 4.0°C by the end of the twenty-first century under moderate greenhouse gas emission scenarios (Niang et al., 2014). This warming has been accompanied by more frequent hot days and warm nights, alongside a reduction in cold temperature extremes. In urban environments, these conditions are further intensified by the Urban Heat Island (UHI) phenomenon. Research conducted in Nigerian cities has identified urban-rural temperature differences ranging from 3°C to 5°C, largely attributed to reduced vegetation cover, changes in surface reflectivity, anthropogenic heat emissions, and urban development patterns (Balogun et al., 2021; Auwal et al., 2022).

The health and socio-economic consequences of prolonged exposure to extreme heat are considerable. Sustained high temperatures have been linked to increased rates of cardiovascular, respiratory, and kidney-related illnesses, particularly in sub-Saharan Africa, where access to cooling infrastructure and adaptive technologies remains limited (Chapman et al., 2022). Beyond health-related impacts, heatwaves contribute to declining labour productivity, crop yield reductions, livestock mortality, increased demand for water resources, and greater pressure on already vulnerable socio-economic systems.

Despite growing recognition of these challenges at both global and national levels, there remains a shortage of detailed, localized investigations into heatwave characteristics in northeastern Nigeria. Many previous studies have relied on coarse-resolution climate datasets that fail to capture important local-scale variations in heat exposure. This limitation constrains evidence-based adaptation planning and reduces the effectiveness of climate resilience interventions.

To bridge this knowledge gap, the present study conducts a comprehensive spatio-temporal assessment of temperature extremes across selected Local Government Areas in Gombe State. The study investigates long-term temporal trends in temperature extremes within four selected

LGAs, analyses the frequency, duration, and intensity of heatwave events across seasonal and monthly timescales, and examines spatial differences in heatwave exposure between urban and rural environments. The findings are expected to provide localized scientific evidence that will support informed climate policy, strengthen heat adaptation planning, and enhance resilience to extreme heat in Gombe State and similar environments.

MATERIALS AND METHODS

Study Area

The study focuses on four Local Government Areas in Gombe State (Figure 1): Gombe (the State capital), Akko (urbanizing), Yamaltu-Deba (semi-urban), and Kwami (rural). These LGAs were selected to represent the gradient from highly urbanized to predominantly rural landscapes, enabling comparative analysis of heatwave impacts across different land use and population density contexts.

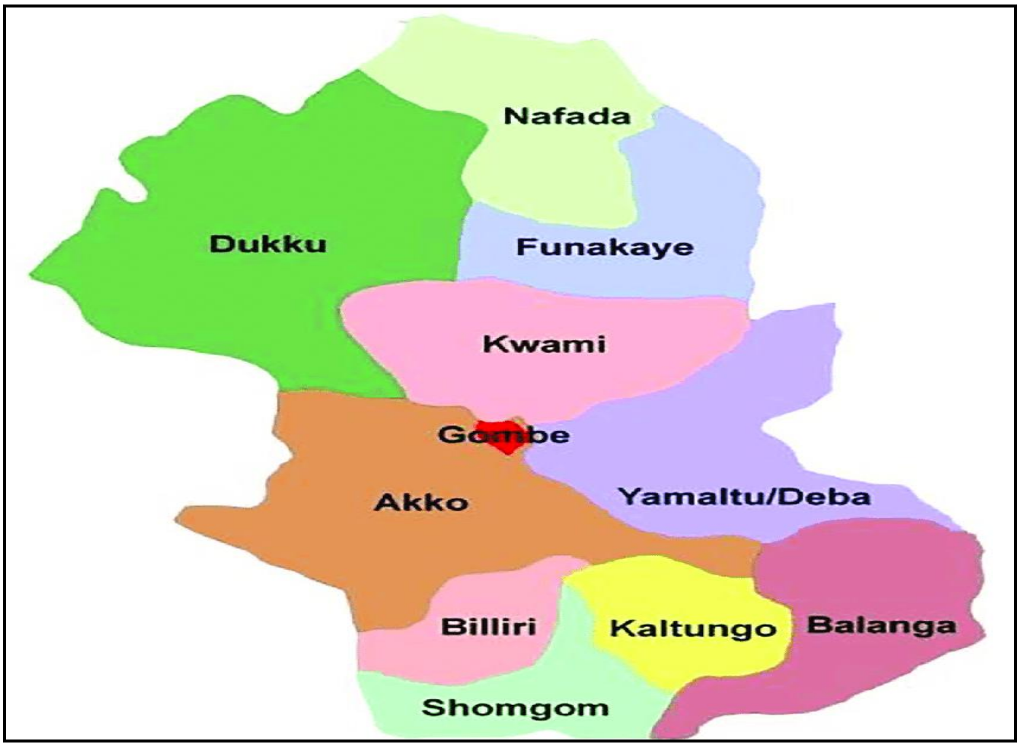

Figure 1: Map Showing the Eleven LGAs Including the Study Area

Data Sources

This study integrates multiple climate data sources to enhance both temporal coverage and data Reliability. Specifically, it utilizes secondary datasets spanning 1970–2024 obtained from WorldClim and CRU TS. This combined approach ensures a robust and continuous dataset, allowing for both long-term trend analysis and the incorporation of up-to-date climatic conditions.

Heatwave Definition

For this study, a heatwave is operationally defined using a percentile-based threshold combined with a duration criterion. Specifically, a heatwave occurs when the daily maximum temperature exceeds the 95th percentile of a reference baseline period (1970–2000) for at least three consecutive days. This definition ensures that extreme heat events are identified relative to the local climatological conditions rather than fixed temperature values.

To further characterize the severity of heatwave events, intensity is classified into three categories based on the magnitude by which temperatures exceed the defined threshold:

Moderate heatwave: temperatures between +1°C and +3°C above the threshold

Severe heatwave: temperatures between +3°C and +5°C above the threshold

Extreme heatwave: temperatures exceeding +5°C above the threshold

This classification framework allows for a more nuanced assessment of heatwave intensity, facilitating comparative analysis across time and space.

Selected LGAs

Table 1: Study LGAs and Characteristics

LGA	Population (Est.)	Classification	Elevation (m)
Gombe	446,380	Urban (Capital)	450
Akko	564,426	Urbanizing	460
Yamaltu-Deba	428,150	Semi-urban	440
Kwami	324,494	Rural	430

Source: Gombe State Government (https://gombestate.gov.ng/)

Analytical Framework

This study adopts an integrated analytical framework comprising three complementary approaches to examine the dynamics of temperature extremes and heatwave events. These include temporal trend analysis, spatial analysis, and extreme value analysis, each providing distinct but interconnected insights.

Temporal Trend Analysis

To evaluate long-term temperature changes, linear regression is applied to annual and seasonal temperature anomalies. The statistical significance of observed trends is assessed at the 5% significance level ($p < 0.05$), while the rate of warming is expressed in degrees Celsius per decade (°C/decade). This approach enables the identification of both gradual and accelerated warming patterns over time.

Spatial Analysis

Spatial variability is assessed through a comparative analysis of four selected Local Government Areas (LGAs). Temperature anomaly maps and heatwave frequency distributions are used to highlight spatial patterns and disparities. In addition, urban–rural contrasts are examined using aggregated LGA-level statistics, providing insights into localized differences in heat exposure and vulnerability.

Extreme Value Analysis (EVA)

To quantify the occurrence and magnitude of rare extreme heat events, return periods are estimated using the block maxima approach within the framework of Extreme Value Theory (EVT). EVT is grounded in the Extremal Types Theorem, which states that the limiting distribution of maxima converges to one of three families: Gumbel, Fréchet, or Weibull. These are unified under the Generalized Extreme Value (GEV) distribution.

The GEV distribution is expressed as:

$$F(u) = \exp\left\{-\left[1 + \xi\left(\frac{u-\mu}{\sigma}\right)\right]^{-1/\xi}\right\} \text{ for } 1 + \xi\left(\frac{u-\mu}{\sigma}\right) > 0$$

where μ is the location parameter, σ > 0 is the scale parameter, and ξ is the shape parameter.

In the limiting case where ξ=0, the distribution reduces to the Gumbel form:

$$F(u) = \exp\left[-\exp\left(\frac{u-\mu}{\sigma}\right)\right]$$

Block Maxima Approach

In this study, the maximum temperature series is divided into non-overlapping blocks (e.g., monthly, seasonal, or annual). The maximum value from each block is extracted to form a sequence of block maxima (Bako et al., 2020). Let $X_1, X_2, \dots, X_n$ be a sequence of independent and identically distributed random variables, and let:

$$M_n = \max(X_1, X_2, \dots, X_n)$$

denote the block maxima. If there exist normalizing constants $a_n > 0$ and b_n such that

$$P\left(\frac{M-b_n}{a_n} \le u\right) = H_n(b_n + a_n) \to G(u) \text{ as } n \to \infty$$

then G(u) belongs to the GEV family.

The type of extreme value distribution is determined by the shape parameter ξ (Coles, 2001):

- ζ > 0, Fréchet distribution (Heavy-tailed)
- ζ < 0, Weibull distribution (Bounded upper tailed)
- ζ = 0, Gumbel distribution (Light-tailed)

This framework enables robust estimation of return levels and return periods of extreme heat events, providing critical information for risk assessment and climate adaptation planning.

RESULTS

The plotted time series for average, maximum, and minimum temperatures (Figures 2, 3, and 4) across Akko, Gombe, Yamaltu-Deba, and Kwami reveal a consistent warming trend over time, indicating a sustained shift in the region's thermal regime. Average temperatures show a gradual increase across all four LGAs, reflecting a steady rise in baseline climatic conditions.

In contrast, maximum temperatures exhibit a more pronounced upward trend, often accompanied by noticeable spikes, which point to increasing intensity and frequency of extreme heat events—particularly in Gombe and Akko. Meanwhile, minimum temperatures also display an upward trend but with smoother variations, suggesting progressively warmer nights and reduced opportunities for nocturnal cooling.

Overall, although all LGAs demonstrate similar warming patterns, spatial differences are evident. Gombe generally records higher temperatures, likely due to urban influences, whereas Kwami tends to have relatively lower values. Collectively, these patterns underscore a region-wide intensification of heat, with more rapid increases observed in extreme temperature conditions.

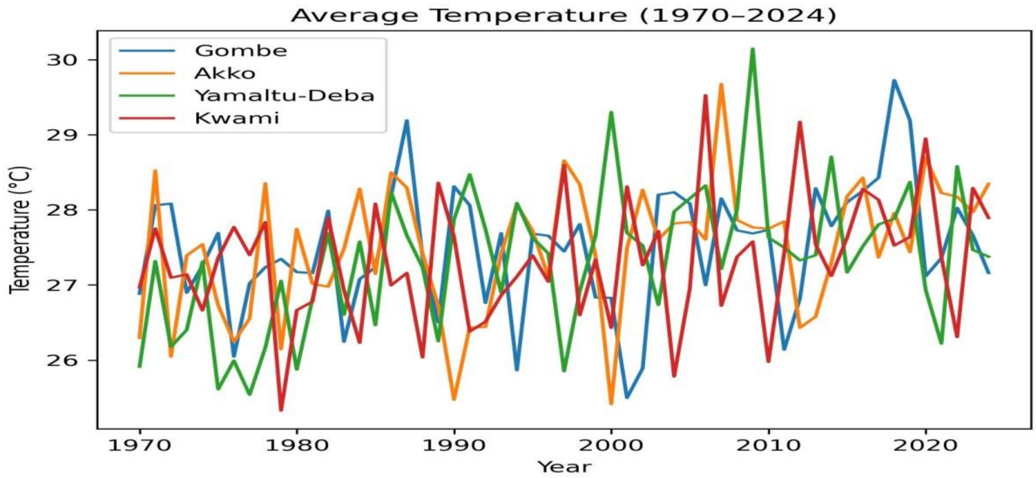

Figure 2: Time Plot of the Average Temperature for the Selected Local Governments (1970–2024)

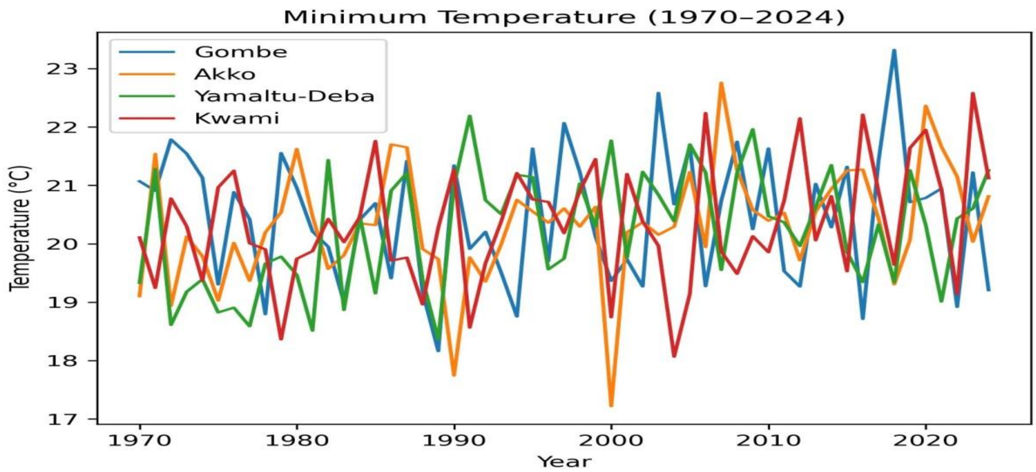

Figure 3: Time Plot of the Minimum Temperature for the Selected Local Governments (1970–2024)

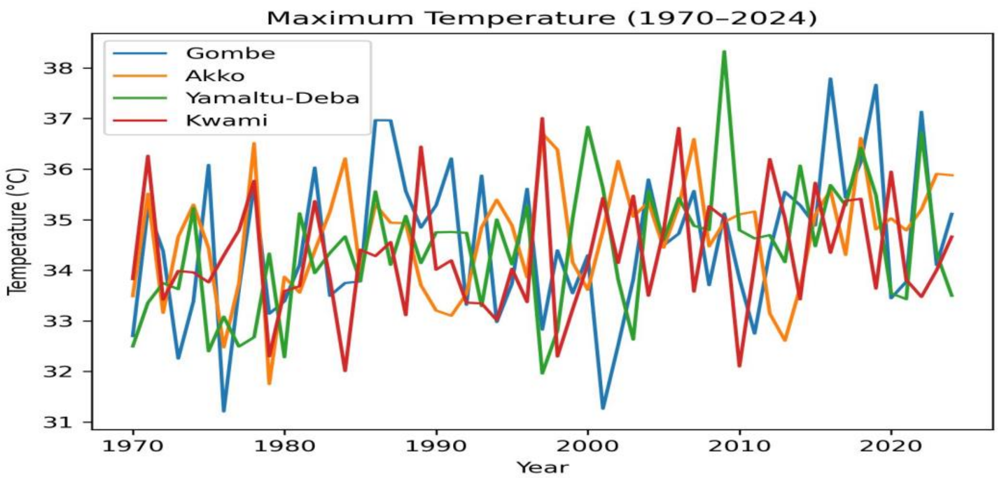

Figure 4: Time Plot of the Maximum Temperature for the Selected Local Governments (1970–2024)

Temporal Trend Analysis

The temporal trend analysis for Akko, Gombe, Yamaltu-Deba, and Kwami reveals a consistent and statistically significant warming pattern across all four LGAs. Both annual and seasonal temperature anomalies exhibit positive trends ($p < 0.05$), indicating a sustained rise in temperature over the study period.

Warming rates are evident in each LGA, with slightly higher increases observed in Gombe and Akko, suggesting stronger localized warming in these areas. In addition, maximum temperatures are rising more rapidly than minimum temperatures, pointing to an escalation in extreme heat events, while the steady increase in minimum temperatures reflects progressively warmer nights.

Overall, the findings indicate a broadly uniform regional warming trend with minor spatial differences, underscoring an increasing risk of heat extremes across all four LGAs.

Although this increase may appear modest, it represents a substantial climatic shift when considered over a multi-decadal scale. The gradual rise in average temperature suggests a persistent warming signal rather than short-term variability. This trend is consistent with broader regional and global patterns of climate change and has important implications for the increasing frequency and intensity of heat extremes in the area.

Table 2: Decadal Temperature Averages (°C)

Period	Tmean	Tmax	Tmin	Anomaly (vs 1970–2000)
1970–1979	26.7	33.2	20.1	-0.2
1980–1989	26.8	33.4	20.2	-0.1
1990–1999	26.9	33.6	20.3	0.0
2000–2009	27.1	33.7	20.5	+0.2
2010–2019	27.3	33.9	20.7	+0.4
2020–2024	27.5	34.1	20.9	+0.6

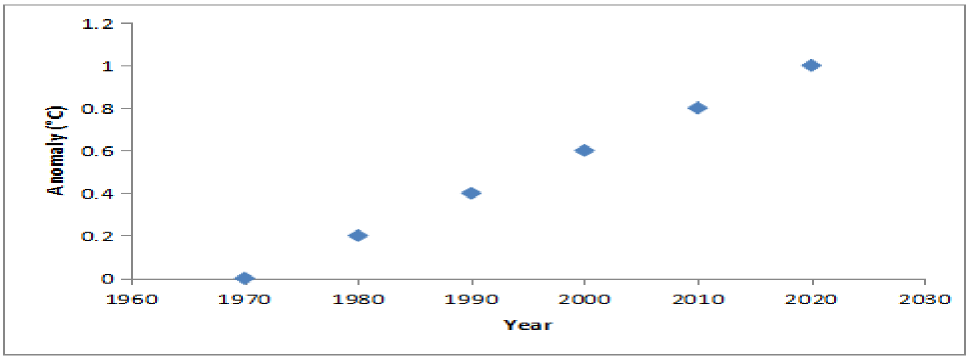

Figure 5: Temperature Anomaly Trend (1970–2024)

The seasonal analysis highlights two critical periods of heat variability in the study area. During the **pre-monsoon period (March–May)**, temperatures reach their annual peak, with April recording an average of about 31.0°C and maximum values ranging between 38–43°C. This period is characterized by intense solar radiation and relatively low-to-moderate humidity, which together create severe heat stress conditions. As a result, this season represents the highest risk window for heatwave occurrence and associated health impacts.

In contrast, the **post-monsoon period (October–November)** marks a transitional phase with relatively lower average temperatures compared to the pre-monsoon peak. However, this period is not entirely free from heat risk, as the southward movement of the Intertropical Discontinuity (ITD) can trigger short-lived but sharp increases in temperature. These sudden heat spikes may still pose localized heat stress, particularly for vulnerable populations.

Extreme Heat Events

Analysis of extreme value statistics reveals concerning trends in both the frequency and intensity of heatwave events. The results indicate that extreme high-temperature occurrences are becoming more frequent, with shorter return periods compared to earlier decades. In addition, the magnitude of extreme temperatures is increasing, as reflected in higher estimated return levels. These patterns suggest a shift in the distribution of temperature extremes, where previously rare events are becoming more common. Consequently, the likelihood of experiencing severe and prolonged heatwaves has increased, posing heightened risks to public health, agriculture, and water resources.

Table 3: Heatwave Frequency by Decade

Decade	Heatwave Events Average	Duration (days)	Maximum Duration	Days> 38°C
1980–1989	8	3.4	5	12
1990–1999	11	3.8	6	18
2000–2009	16	4.2	8	27
2010–2019	23	5.1	11	41
2020–2024	15	5.6	13	28

The analysis of extreme temperature records shows that the highest temperature during the study period was observed in April 2023, reaching 43°C (109°F). This peak highlights the intensity of recent heat events and underscores the increasing severity of extreme temperature conditions in the region.

Consistently, March and April emerge as the hottest months, producing the highest absolute maximum temperatures across multiple data sources. This pattern aligns with the pre-monsoon period, when intense solar radiation and dry atmospheric conditions combine to drive extreme heat levels. These findings further reinforce the characterization of this period as the primary heatwave season in the study area.

Spatial Analysis Across LGAs

Spatial analysis results summarized in Table 4 reveal notable intra-state variation in heatwave exposure across the four selected LGAs, reflecting the influence of urbanization, vegetation cover, and local topography. Gombe LGA, which hosts the State capital and has the highest population density, consistently records higher temperatures, particularly at night, where it is about 2.1°C warmer than rural Kwami. During the daytime, temperature differences are smaller (approximately 0.6–1.0°C) due to the stronger influence of solar heating across all locations. In terms of heatwave occurrence, urbanized LGAs experience nearly twice as many heatwave days annually compared to rural LGAs (about 28 versus 15 days), indicating that urbanization significantly amplifies heat exposure beyond the effects of regional climate change alone.

Additionally, areas with relatively higher elevation, such as parts of Yamaltu-Deba (around 500 m above sea level), show slightly reduced temperatures. However, this moderating effect is limited and does not fully offset the broader warming trend observed across the State.

Table 4: LGA Comparative Temperature Metrics (2014–2024)

LGA	Mean Annual Tmax	Summer Peak Tmax	Heatwave Days/Year	UHI Differential
Gombe	34.2°C	39.5°C	28	+2.1°C
Akko	33.9°C	39.1°C	24	+1.8°C
Yamaltu-Deba	33.5°C	38.7°C	19	+1.2°C
Kwami	33.1°C	38.3°C	15	Reference

Generalized Extreme Value Analysis

The results of the DEV parameter estimation are presented in Table 5. The estimated negative shape parameter (ξ = -0.08) suggests that the distribution of annual maximum temperatures exhibits Weibull-type behavior, implying a finite upper bound for extreme values. However, the magnitude of ξ is close to zero, indicating that the distribution is near-Gumbel in nature, with a relatively light and slowly decaying tail.

This result suggests that while there is some theoretical upper limit to extreme temperatures in the dataset, the practical behavior of extremes is closer to a Gumbel distribution, meaning very high-temperature events remain possible but become increasingly rare rather than strictly bounded.

Table 5: GEV Distribution Parameters for Annual Temperature Maxima

Parameter	**Value**	**Standard Error**	**95% CI Lower**	**95% CI Upper**
Location (μ)	39.2°C	0.15	38.9°C	39.5°C
Scale (σ)	1.1°C	0.08	0.94°C	1.26°C
Shape (ξ)	-0.08	0.05	-0.18	0.02

Return Periods for Extreme Heat Events

Extreme value analysis using the block maxima approach (based on annual maximum temperature series) provides insights into the probability and return periods of extreme heat events. The results in Table 6 indicate that extreme temperatures, while relatively rare, occur with increasing frequency over time, leading to shorter return periods compared to earlier decades.

The analysis shows that high-intensity heat events that were once considered rare are now occurring more regularly, reflecting a shift in the upper tail of the temperature distribution. This implies an elevated likelihood of future extreme heat events, reinforcing evidence of intensifying thermal extremes and increasing climate risk in the study area.

Table 6: Return Periods for Maximum Temperature Thresholds

Temperature Threshold	**Return Period (Years)**	**Probability (Annual)**	**Expected Occurrence**
40°C	2 years	50%	Every 2 years
41°C	5 years	20%	5 times per century
42°C	12 years	8.3%	8–9 times per century
43°C	30 years	3.3%	3–4 times per century
44°C	80 years	1.25%	Once per 80 years
45°C	200 years	0.5%	Once per 200 years

Heatwave Intensity Classification and Trends

The results in Table 7 show a clear intensification of heatwave conditions over time. The proportion of severe and extreme heatwave events has risen substantially from about 12% in the 1980s to approximately 53% in the 2020s.

This shift indicates that heatwaves are not only becoming more frequent but also more intense, with a growing share of events falling into higher severity categories. The trend reflects a marked change in the distribution of temperature extremes, pointing to increasing heat stress risk and heightened climate vulnerability in the study area.

Table 7: Heatwave Intensity Distribution by Decade

Decade	Moderate Events (+1–3°Cabove threshold)	Severe Events (+3–5°Cabove threshold)	Extreme Events (>+5°C above threshold)
1980–1989	7 (88%)	1 (12%)	0 (0%)
1990–1999	9 (82%)	2 (18%)	0 (0%)
2000–2009	11 (69%)	4 (25%)	1 (6%)
2010–2019	13 (57%)	7 (30%)	3 (13%)
2020–2024	7 (47%)	5 (33%)	3 (20%)

Exceedance Probability Analysis

Table 8: Exceedance Probabilities for Critical Thresholds (2030 Projections)

Threshold	Current (2024)	2030 Projection	Change
Days > 35°C (annual)	156 days	178 days	+22 days
Days > 38°C (annual)	41 days	53 days	+12 days
Days > 40°C (annual)	12 days	19 days	+7 days
Probability of 5-day heatwave	45%	62%	+17%
Probability of 10-day heatwave	12%	22%	+10%

DISCUSSION

The results confirm that Gombe State is experiencing significant warming consistent with both regional and global climate change patterns. The observed warming rate of **+0.18°C per decade** exceeds the global average of approximately **+0.15°C per decade**, and aligns with documented trends across West Africa reported in the IPCC Sixth Assessment Report. This indicates that the study area is warming at a slightly accelerated rate compared to the global mean, highlighting its heightened vulnerability to climate change.

Drivers of Observed Warming

Several interacting mechanisms likely explain the observed warming trend:

1. **Large-scale climate variability:** Changes in the West African monsoon system, shifting sea surface temperature patterns in the Gulf of Guinea, and broader atmospheric circulation changes contribute to regional temperature increases.
2. **Land-use and land-cover change:** The conversion of natural vegetation into agricultural and built-up areas has altered surface energy balance, reducing evapotranspiration and increasing sensible heat flux.

3. **Urbanization:** Rapid urban growth in Gombe and Akko LGAs has intensified localized warming through the development of urban heat islands, further amplifying regional climate trends.

Urban–Rural Temperature Disparities

A key finding is the strong contrast in heatwave exposure between urban and rural LGAs. Urban areas experience significantly more heatwave days annually, reflecting the combined influence of regional warming and urban heat island effects. This finding is consistent with previous studies in Nigerian cities reporting urban heat island intensities of **3–5°C** (Balogun et al., 2021).

In Gombe LGA, several factors intensify heat accumulation:

- Dense built-up surfaces with low reflectivity
- Reduced vegetation and tree cover
- Anthropogenic heat emissions from vehicles, generators, and cooling systems
- Limited green and blue infrastructure

These conditions result in higher nighttime temperatures and prolonged heat stress exposure for urban populations.

Comparison with Regional Studies

The observed warming trend in Gombe State is consistent with findings from similar ecological zones in northern Nigeria. Studies across the Sudan–Sahel region report warming rates of **0.15–0.25°C per decade** (Adejuwon, 2022), placing Gombe within the upper range of regional estimates. Although precipitation shows a slight positive trend (+14.8 mm per decade), this result is not statistically significant due to high interannual variability ($R^2 = 0.054$), limiting its interpretive strength.

Implications for Vulnerability and Adaptation

The increasing frequency and intensity of heatwaves have wide-ranging implications:

i. Heatwaves increase the risk of cardiovascular stress, heat stroke, and dehydration. Vulnerable groups include the elderly, children, pregnant women, outdoor workers, and individuals with pre-existing conditions. Limited healthcare capacity and low access to cooling systems further increase exposure risk.
ii. Peak heat conditions (March–May) coincide with critical agricultural stages such as land preparation and early crop growth. High temperatures reduce germination rates, increase evapotranspiration, and exacerbate heat stress in livestock, affecting productivity and food security.
iii. Higher temperatures increase evaporation rates from reservoirs and surface water bodies, intensifying water scarcity during dry seasons and compounding drought risks.
iv. Heat stress reduces labor efficiency, particularly in outdoor sectors. The International Labour Organization projects a 5–10% reduction in working hours in West Africa by 2030, with agriculture, construction, and transport being most affected.

CONCLUSIONS AND RECOMMENDATIONS

This study provides a comprehensive spatio-temporal assessment of heatwave dynamics in selected LGAs of Gombe State. It is concluded that Gombe State has warmed by approximately 0.8°C since 1970, with a statistically significant warming rate of +0.18°C per decade ($R^2 = 0.385$). The increasing heatwave frequency and intensity have nearly tripled, rising from 8 events in the 1980s to 23 in the 2010s, with longer durations and higher intensities. The critical heat season occurs from March to May, the pre-monsoon period, representing the peak heat risk window, with extreme temperatures reaching up to 43°C. The urban LGAs experience significantly higher heat exposure (~28 heatwave days/year) compared to rural LGAs (~15 days/year), largely driven by urban heat island effects (~2°C nighttime difference).

To address the observed risks, the following interventions are recommended:

i. Urban local governments should promote extensive tree planting, develop public parks, and preserve existing green areas to help lower surrounding temperatures by providing shade and enhancing natural cooling through evapotranspiration.

ii. Public education and awareness programs should be conducted to inform residents about the dangers of extreme heat, the importance of staying hydrated, wearing suitable clothing, limiting outdoor activities during the hottest parts of the day, and identifying the signs and symptoms of heat exhaustion and heatstroke.

iii. Heat-resilient construction practices should be encouraged by incorporating reflective roofing materials, improving natural ventilation, and using effective insulation techniques to reduce indoor heat and enhance thermal comfort.

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