
TEMPORAL AND SPATIAL PATTERNS OF SEVERE WARM HARMATTAN (SWH) EVENTS IN NORTHERN NIGERIA

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Abstract

This study examined the temporal and spatial patterns of Severe Warm Harmattan (SWH) events in Northern Nigeria from 1965 to 2024. Monthly minimum temperatures for the harmattan seasons, spanning November to February, were collected for seven stations in Northwestern Nigeria, namely Birnin Kebbi, Sokoto, Gusau, Katsina, Kano, Dutse, and Kaduna, and for six stations in Northeastern Nigeria, namely Damaturu, Maiduguri, Bauchi, Gombe, Yola, and Jalingo, and analysed across the sixty year study period. A cross-regional comparison and a decadal analysis were conducted, and the Standard Anomaly Index was applied to identify SWH events. The findings revealed that SWH events occurred 142 times in Northwestern Nigeria and 116 times in Northeastern Nigeria, totalling 258 occurrences across Northern Nigeria. In the Northwestern region, Kaduna recorded the highest frequency of SWH events at 31 occurrences, while Sokoto recorded the lowest at 11. In the Northeastern region, Gombe recorded the highest at 24 occurrences, while Jalingo recorded the lowest at 17. SWH events were concentrated in November and February, the transitional months of the harmattan season. Among decades, the first decade exhibited the highest occurrence in Northwestern Nigeria, while the 2005 to 2014 decade showed the highest frequency in the Northeastern region. The decadal frequencies revealed no uniform trend between the two regions, yet all stations documented anomalous warming, underscoring the growing influence of climate change on the harmattan season and the attendant implications for public health and adaptation planning.

Keywords: Northern Nigeria, severe warm harmattan, anomalous warm events, standard anomaly index, climate change, harmattan season

1. Introduction

Global temperature patterns across all seasons are undergoing significant transformation, with periods traditionally characterised by cold weather increasingly recording unusual thermal events that are largely attributed to the accelerating influence of climate change (Molina et al., 2025). Over the past century, anthropogenic activities such as deforestation, industrial operation, and the burning of fossil fuels have shifted global weather and climate in noticeable ways (Rahmani and Ahmadi, 2024). These changes have precipitated anomalous episodes, including severe and extreme warm events, even during periods normally associated with cold seasonal conditions. Bolan et al. (2024) report that anthropogenic climate change has increased the likelihood or severity of roughly seventy one percent of documented extreme weather events.

Unusual warm episodes occur more frequently during typically cold seasons such as winter and harmattan, a pattern linked directly to global warming (Skrzynska and Twardosz, 2023). Across regions ranging from Europe and North America to Asia and parts of Africa, such events have recurred decade after decade with varying intensity. This is of particular concern for the harmattan zone of Northern Nigeria, where conditions traditionally cold during the harmattan season now exhibit warming episodes that defy seasonal expectation. The temporal dynamics and regional distribution of these events nonetheless remain insufficiently understood (Folorunsho et al., 2023).

Anomalous warm events within cold seasons extend beyond temperature anomalies to encompass significant health consequences. Unusually warm harmattan conditions are associated with dehydration, muscle cramps, headaches, fatigue, sleep disturbance, and renal complications (Sufiyan et al., 2020). Examining the temporal and spatial patterns of SWH events in Northern Nigeria is therefore essential, since understanding their occurrence over decades and across regions equips stakeholders with the insight required for mitigation planning, policy formulation, and the reduction of health impacts on exposed populations.

2. Literature Review

2.1 Conceptual and Empirical Review

The harmattan, a dry northeast trade wind of Saharan origin, prevails between November and February and traditionally brings cold, dry conditions to the West African Sahel, profoundly influencing regional climate and human health (Folorunsho et al., 2023). Anthropogenic climate change has disrupted these patterns, producing anomalous Severe Warm Harmattan events that deviate sharply from historical norms and reflect broader Sahel variability driven by oceanic and atmospheric teleconnections, land-surface feedbacks, and regional warming that exceeds the global average (Chagnaud et al., 2022). Understanding these phenomena requires examination across intra-seasonal and inter-decadal timescales, since the proportion of cold seasons marked by severe or extreme temperatures is increasingly deviating from established baselines (Maignan et al., 2008).

The empirical record from other regions is instructive. Maignan et al. (2008) documented widespread warming and mild winters across Western Europe, while Twardosz et al. (2015) found exceptionally mild winters peaking in frequency during the most recent decades of their analysis. Jordan (2016) reported significant increases in severe warm winters in the western United States, and Kam et al. (2022) linked a record-breaking warm winter in Northwest Russia to anthropogenic influence. In Africa, Fazel-Rastgar and Sivakumar (2022) identified unusual warm episodes during cold winters in South Africa, and Van der Walt and Fitchett (2021) documented an increased frequency of warm extremes across multiple regions of the country. Despite documented reports of SWH events in Nigeria, no known study has systematically examined their temporal dynamics or regional distribution across the full 1965 to 2024 interval, a gap the present study addresses by extending the methodological approach of Folorunsho et al. (2024) over a longer horizon and a wider spatial coverage.

2.2 Theoretical Framework

The study is anchored in the greenhouse effect theory, first advanced by Svante Arrhenius, which holds that rising concentrations of greenhouse gases trap outgoing longwave radiation and warm the lower atmosphere. The theory provides the mechanistic basis for interpreting anomalous warming during a season historically defined by cold, since the enhanced radiative forcing raises minimum temperatures and increases the likelihood of severe warm episodes even under the prevailing harmattan circulation.

3. Study Area, Materials and Methods

The study covered thirteen meteorological stations across Northern Nigeria, comprising seven in the Northwestern region, namely Birnin Kebbi, Sokoto, Gusau, Katsina, Kano, Dutse, and Kaduna, and six in the Northeastern region, namely Damaturu, Maiduguri, Bauchi, Gombe, Yola, and Jalingo. These are the principal stations located in the state capitals of the two regions, ensuring comprehensive coverage with no station omitted. Figure 1 displays the spatial distribution of the selected stations across the two regions.

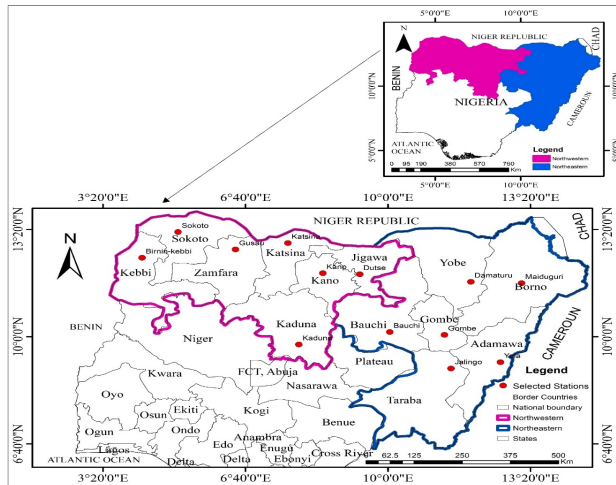


Figure 1. Study area showing the thirteen selected meteorological stations across the Northwestern and Northeastern regions of Northern Nigeria.

Source: Authors' cartographic compilation.

Mean monthly minimum temperature data for the harmattan seasons spanning the sixty years from 1965 to 2024 were obtained from the World Bank Group Climate Change Knowledge Portal and from prior scholarly works (Folorunsho, 2025; Olatunde et al., 2026). Complete datasets were obtained with no missing values. The Standard Anomaly Index was used to identify Severe Warm Harmattan events for all harmattan months, and is defined in Equation 1,

$$x_i = (r - r_i) / \sigma \quad (1)$$

where r is the temperature mean of the year, r_i is the long-term mean, and σ is the standard deviation of the annual mean temperature over the long term (Folorunsho et al., 2024). The index categorisation in Table 1 was adapted from prior work, with the present study utilising the minimum temperature range of 1.29 to 1.65 to classify months in which a Severe Warm Harmattan event occurred. The percentage contribution of each station was computed through Equation 2,

$$\text{Percentage} = (n / \Sigma n) \times 100 \quad (2)$$

where n is the number of SWH occurrences at a given station and Σn is the total across all stations. The sixty year period was divided into six decadal intervals for the temporal analysis.

Table 1. Intensities of minimum temperature of the harmattan seasons in the study area.

Minimum temperature intensity	Range of SAI category
Extreme Warm Harmattan	1.66 to 2.00
Severe Warm Harmattan	1.29 to 1.65
Moderate Warm (Mild) Harmattan	0.85 to 1.28
Near Normal Harmattan	-0.84 to +0.84
Moderate Cold (Cool) Harmattan	-0.85 to -1.28
Severe Cold Harmattan	-1.29 to -1.65
Extreme Cold Harmattan	-1.66 to -2.00

Adapted from: Folorunsho et al. (2024).

4. Results and Discussion

4.1 SWH Events in Northwestern Nigeria

Table 2 summarises the occurrence of SWH events across the seven Northwestern stations over the study period. The events occurred 142 times in total, with marked variation in spatial distribution and monthly concentration. Of the total, 87 events, or about 61 percent, occurred in February and 51 events, or about 36 percent, in November, while only three events occurred in January and one in December. Kaduna experienced the highest frequency with 31 occurrences, followed by Dutse with 28 and Gusau with 25, while Sokoto recorded the lowest at 11. The high frequency at Kaduna is notable given its position as the southernmost station, where warmer conditions during harmattan are more likely as the harmattan wind weakens with distance from the Sahara (Folorunsho et al., 2023).

Table 2. Summary of SWH events in Northwestern Nigeria (1965 to 2024).

Station	Nov	Dec	Jan	Feb	Total	%
Birnin Kebbi	6	—	—	13	19	13.38
Sokoto	7	—	—	4	11	7.75
Gusau	2	—	3	20	25	17.61
Katsina	10	—	—	3	13	9.15
Kano	9	—	—	6	15	10.56
Dutse	17	1	—	10	28	19.72
Kaduna	—	—	—	31	31	21.83
Total	51	1	3	87	142	100

Source: Analysis of data (2024).

Figure 2 contrasts the station frequencies in the two regions, making plain the dominance of Kaduna and Dutse in the Northwest and of Gombe and Bauchi in the Northeast.

Station-wise Frequency of Severe Warm Harmattan Events (1965-2024)

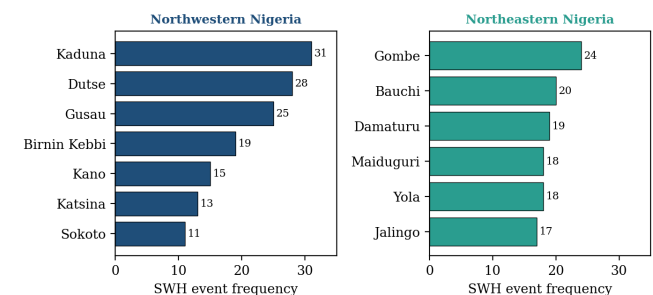


Figure 2. Station-wise frequency of SWH events in the Northwestern and Northeastern regions, 1965 to 2024.

Source: Authors' computation from data.

4.2 SWH Events in Northeastern Nigeria

Table 3 summarises the occurrence across the six Northeastern stations, where SWH events occurred 116 times. As in the Northwest, the events concentrated in the transitional months, with 67 in February and 48 in November. Gombe recorded the highest frequency with 24 occurrences, followed by Bauchi with 20 and Damaturu with 19, while Jalingo recorded the lowest at 17. The relative uniformity across stations is greater than in the Northwest, reflecting the more homogeneous continental setting of the Northeastern region.

Table 3. Summary of SWH events in Northeastern Nigeria (1965 to 2024).

Station	Nov	Dec	Jan	Feb	Total	%
Damaturu	15	–	–	4	19	16.38
Maiduguri	6	–	–	12	18	15.52
Bauchi	9	–	–	11	20	17.24
Gombe	6	–	–	18	24	20.69
Yola	6	–	–	12	18	15.52
Jalingo	6	–	1	10	17	14.66
Total	48	–	1	67	116	100

Source: Analysis of data (2024).

Figure 3 displays the monthly distribution of events across the harmattan season for both regions, confirming that the transitional months of November and February account for almost all SWH occurrences while the deep harmattan months of December and January remain comparatively quiescent.

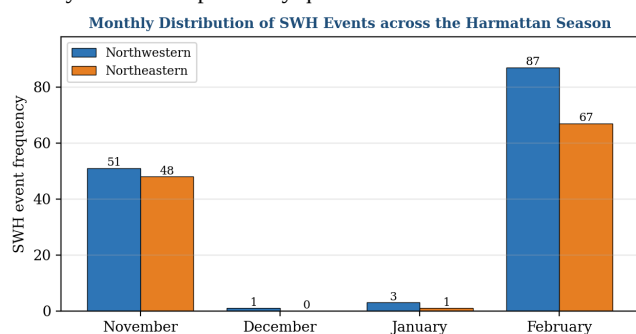


Figure 3. Monthly distribution of SWH events across the harmattan season in the two regions.

Source: Authors' computation from data.

4.3 Decadal and Cross-regional Patterns

Table 4 presents the cross-regional decadal comparison. In Northwestern Nigeria the first decade of 1965 to 1974 and the fifth decade of 2005 to 2014 jointly recorded the highest frequency at 30 events each, whereas in the Northeastern region the fifth decade alone recorded the peak at 26 events. The combined totals reveal two pronounced maxima, in the earliest and the penultimate decades, separated by a relative lull in the middle decades, and the decadal frequencies show no uniform trend common to both regions. Crucially, the most recent decade of 2015 to 2024 sustained 20 events in each region, indicating that anomalous warming during the harmattan season persists as a significant climatic feature rather than fading.

Table 4. Cross-regional comparison of SWH events by decade (1965 to 2024).

Decade	Northwest	%	Northeast	%	Total	%
1965-1974	30	21.13	23	19.83	53	20.54
1975-1984	21	14.79	18	15.52	39	15.12
1985-1994	20	14.08	13	11.21	33	12.79
1995-2004	21	14.79	16	13.79	37	14.34
2005-2014	30	21.13	26	22.41	56	21.71
2015-2024	20	14.08	20	17.24	40	15.50
Total	142	100	116	100	258	100

Source: Analysis of data (2024).

Figure 4 visualises the decadal distribution by region, and Figure 5 traces the combined decadal trend across Northern Nigeria, both confirming the twin maxima and the absence of a single monotonic trajectory.

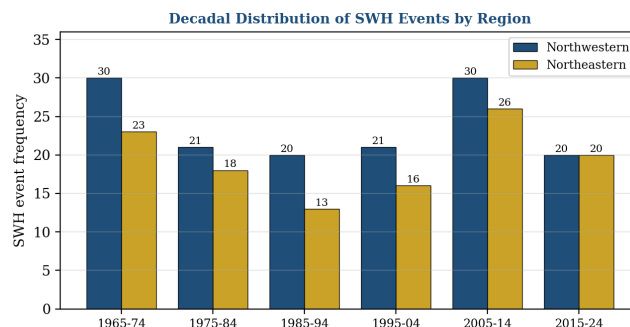


Figure 4. Decadal distribution of SWH events by region.

Source: Authors' computation from data.

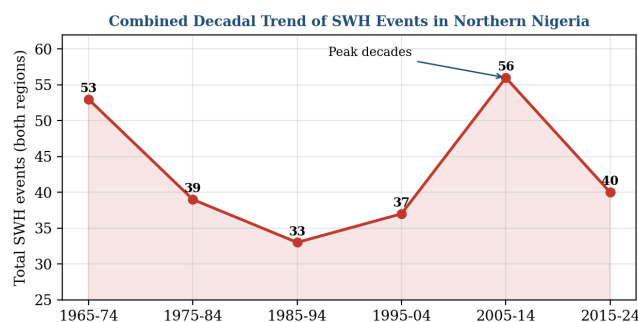


Figure 5. Combined decadal trend of SWH events across Northern Nigeria.

Source: Authors' computation from data.

The persistence of SWH events into the most recent decade, set against the early maximum, suggests that anomalous warm conditions that were once comparatively rare are now recurring with sufficient regularity to constitute a defining feature of the contemporary harmattan. This pattern is consistent with the regional warming reported across the West African Sahel and with the broader body of evidence linking warm seasonal anomalies to anthropogenic climate change (Van der Walt and Fitchett, 2021; Osso et al., 2022). The concentration of events in the transitional months further indicates that the boundaries of the harmattan season, rather than its core, are where the warming signal is most strongly expressed.

5. Conclusion and Recommendations

This study examined the temporal and spatial patterns of Severe Warm Harmattan events across Northern Nigeria from 1965 to 2024. The events occurred 142 times in the Northwestern region and 116 times in the Northeastern region, totalling 258 occurrences, and concentrated overwhelmingly in the transitional months of November and February. Kaduna and Gombe recorded the highest frequencies in their respective regions, while Sokoto and Jalingo recorded the lowest. The decadal analysis revealed two maxima, in the earliest and penultimate decades, with no uniform trend shared by the two regions, yet the persistence of events into the most recent decade confirms that anomalous warming during the harmattan season remains a significant and continuing feature. The health implications are considerable, since SWH events expose residents, and especially the elderly, children, and outdoor workers, to heat exhaustion, dehydration with attendant renal

complications, and disturbed sleep. It is recommended that governments strengthen climate change mitigation through renewable energy and sustainable land use, establish early warning systems for anomalous warm events, mount public health awareness campaigns, support vulnerable populations, and invest in climate research to clarify the atmospheric dynamics driving these patterns and to project their future trajectory under different scenarios.

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