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Assessment of Climate Variability and Associated Health Implications under Cyclonic and Anticyclonic Atmospheric Conditions in Ado-Ekiti, Southwestern Nigeria

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ABSTRACT
Atmospheric circulation systems play a crucial role in regulating rainfall occurrence and environmental conditions within tropical upland regions. This study examines climate variability and associated health implications under cyclonic and anticyclonic atmospheric conditions in Ado-Ekiti, Southwestern Nigeria. Meteorological parameters comprising atmospheric temperature, ambient temperature, wind speed, and precipitation probability were obtained from the Meteoblue database and analysed using descriptive time-series techniques. The results indicate a pronounced diurnal cycle characterized by progressive warming from morning to afternoon hours followed by gradual cooling during the evening. Rainfall probability exhibited a delayed response relative to peak temperature conditions, reaching maximum values during the late afternoon and evening periods. Wind speed showed moderate variability throughout the observation period and remained within a relatively stable range. The findings suggest that precipitation occurrence in the study area is primarily controlled by local thermodynamic processes, moisture availability, and topographic influences rather than strong synoptic-scale disturbances. The observed climatic behaviour has important implications for flood susceptibility, water-resource management, thermal stress exposure, and the transmission of climate-sensitive diseases. The study provides insight into the atmospheric mechanisms governing rainfall variability in upland environments and highlights the importance of integrating meteorological information into environmental planning and public-health adaptation strategies.

Keywords:
Climate variability,
Cyclones,
Anticyclones,
Rainfall probability,
Public health.

INTRODUCTION

Climate variability remains a major driver of environmental change and socio-economic vulnerability across tropical regions. Variations in atmospheric circulation patterns influence temperature distributions, moisture transport, cloud formation processes, and rainfall occurrence, thereby affecting agricultural productivity, ecosystem stability, water resources, and public health (Patz et al., 2020). Understanding the mechanisms responsible for these climatic fluctuations has become increasingly important because of the growing frequency of weather-related hazards and their impacts on human populations.

Among the dominant atmospheric systems controlling regional weather conditions are cyclones and anticyclones. Cyclonic systems are generally associated with low-pressure centres that promote air convergence and upward motion, facilitating cloud formation and precipitation development. Anticyclonic systems, by contrast, are characterized by descending air masses and relatively stable atmospheric conditions that often suppress rainfall generation. The alternating influence of these systems contributes significantly to temporal variations in precipitation and temperature across many climatic zones (Flaounas et al., 2021; Gnann et al., 2025). The influence of atmospheric circulation becomes more complex in areas characterized by significant topographic variation (Gxasheka et al., 2023). Elevated terrain modifies airflow characteristics and moisture transport pathways, producing localized climatic conditions that may differ substantially from those observed in neighbouring lowland regions. Orographic forcing enhances vertical air motion when moisture-laden air masses encounter elevated surfaces, frequently leading to intensified condensation and rainfall formation (Spiridonov et al., 2025; Levizzani & Kidd, 2025). Consequently, upland regions represent important natural laboratories for investigating interactions between atmospheric circulation and terrain-induced climatic modification.

Rainfall variability within upland environments has direct implications for environmental sustainability and human welfare. Excessive precipitation may increase the occurrence of flooding, soil erosion, landslides, and deterioration of water quality, whereas reduced rainfall can contribute to drought conditions, agricultural losses, and increased thermal stress (Chukwuma, 2024). Such environmental changes frequently translate into public-health challenges, including outbreaks of waterborne diseases, sanitation-related problems, respiratory complications, and heat-related illnesses. Therefore, evaluating the climatic processes responsible for rainfall variability is essential for both environmental management and health-risk assessment (Mulla et al., 2023).

Previous studies have demonstrated the significance of atmospheric circulation systems in controlling precipitation behaviour. Investigations have highlighted the role of cyclonic activity in enhancing rainfall intensity through moisture convergence and atmospheric instability, while anticyclonic dominance has been linked to rainfall suppression and prolonged dry conditions (Anandh & Vissa, 2022; Barnes et al., 2023). Recent advances in climate modelling and observational techniques have further improved understanding of temperature dynamics, precipitation variability, and weather-related health impacts. Nevertheless, studies integrating atmospheric variability, topographic influences, and public-health implications within upland environments of Southwestern Nigeria remain limited (Areola, 2024; Ifedayo, 2022).

Ado-Ekiti presents an ideal setting for examining these interactions because of its elevated terrain, pronounced wet and dry seasons, and susceptibility to weather-related environmental challenges. The city experiences substantial seasonal variability in temperature and rainfall, while local topographic characteristics exert considerable influence on atmospheric processes. Despite the environmental importance of the region, limited empirical evidence exists regarding the relationships among temperature variation, wind dynamics, precipitation probability, and associated health implications (Wu et al., 2016).

This study therefore investigates temporal variations in atmospheric temperature, ambient temperature, wind speed, and precipitation probability in Ado-Ekiti under contrasting atmospheric conditions. Particular attention is given to understanding the mechanisms governing rainfall occurrence and evaluating their potential consequences for environmental conditions and public health. The findings contribute to improved knowledge of climate variability in tropical upland environments and provide useful information for climate adaptation planning and risk management.

MATERIALS AND METHODS

Study Area

The investigation was conducted in Ado-Ekiti, the administrative capital of Ekiti State in southwestern Nigeria. The study area is located between latitudes 7.537°N and 7.674°N and longitudes 5.106°E and 5.399°E. The region is characterized by undulating topography with elevations ranging from approximately 325 m to 731 m above mean sea level, resulting in pronounced terrain variability across relatively short spatial distances. Ado-Ekiti experiences a tropical wet-and-dry climatic regime characterized by distinct rainy and dry seasons. The rainy season typically extends from April to October, while relatively dry conditions prevail between November and March. Mean annual rainfall is influenced by both regional atmospheric circulation and local topographic effects, making the area suitable for investigating interactions among temperature, wind conditions, and precipitation processes. The combination of elevated terrain and marked seasonal climatic variability provides an appropriate framework for assessing atmospheric dynamics associated with rainfall generation. Figure 1 shows the topographic map, elevation, and terrain of Ado-Ekiti.

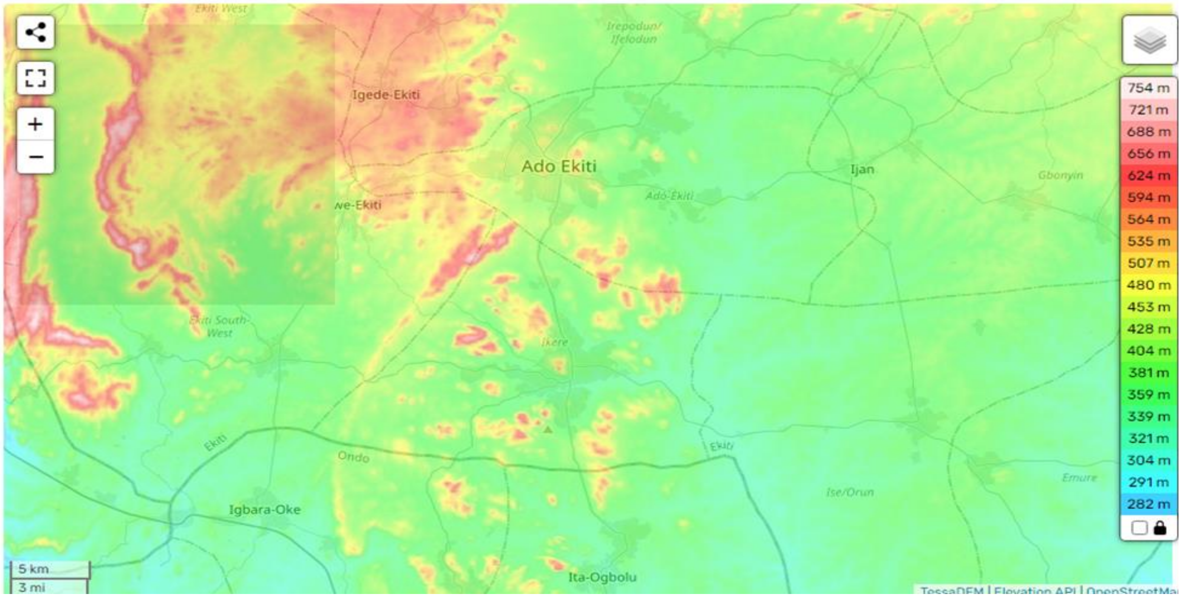

Figure 1: Topographic characteristics and elevation distribution within the study area
Location: 7.53725°N–7.67424°N, 5.10644°E–5.39928°E
Mean Elevation: 430 m

Data Collection

Meteorological data used in this study was obtained from the Meteoblue weather database. The dataset consisted of atmospheric temperature, ambient temperature, wind speed, and precipitation probability measurements recorded at three-hour intervals. The selected observation periods were chosen to capture the complete diurnal evolution of meteorological conditions and facilitate examination of temporal relationships among climatic variables. In addition to meteorological observations, topographic information describing elevation and terrain characteristics was incorporated into the analysis to account for potential orographic influences on rainfall development. The integration of atmospheric and topographic datasets enabled a more comprehensive assessment of the mechanisms governing precipitation variability within the upland environment.

Analytical Procedures

A descriptive time-series framework was employed to evaluate temporal variations in the selected meteorological variables. Sequential changes in atmospheric temperature, ambient temperature, wind speed, and precipitation probability were examined to identify recurring patterns and determine their relationships with rainfall occurrence. The analysis focused on ccharacterization of diurnal temperature variability and its influence on atmospheric conditions, evaluation of precipitation probability patterns and their temporal association with thermal processes, and aassessment of wind-speed behaviour and its contribution to moisture transport and rainfall development. Comparative examination of multiple observation periods was undertaken to determine the consistency of atmospheric responses and identify common climatic characteristics within the study area. Particular attention was given to the temporal lag between peak temperature conditions and maximum precipitation probability, as this relationship provides insight into the thermodynamic processes responsible for convective rainfall formation. The analytical approach further facilitated interpretation of the potential environmental and health implications associated with observed climatic variability, thereby linking atmospheric processes to broader sustainability and public-health considerations.

Table 1: Variation of Atmospheric and Ambient Temperature with Time

Time (hr)	Atmospheric Temperature (℃)			Ambient Temperature (℃)			Wind speed/ wind gust (Km/hr)			Precipitation probability (%)		
#	i	ii	iii	i	ii	ii	i	ii	iii	i	ii	iii
300	24	24	24	28	28	28	13	13	15	0	0	15
600	23	23	24	27	28	28	13	10	11	0	0	15
900	26	27	26	29	31	30	21	12	17	0	0	15
1200	31	31	29	34	35	34	23	14	19	0	50	30
1500	33	30	31	36	35	35	20	15	15	15	85	30
1800	30	27	28	32	32	32	19	11	14	65	95	30
2100	27	25	25	30	30	29	16	13	14	40	70	40
0	25	24	24	28	28	28	15	15	13	15	30	30

RESULTS AND DISCUSSION

Temporal Variability of Atmospheric and Ambient Temperature

The temporal evolution of atmospheric and ambient temperatures revealed a well-defined diurnal cycle across the three observation periods presented in Table 1 and Figures 2–4. In all cases, temperatures remained relatively low during the early morning hours (0300–0600 h), increased progressively after sunrise, and reached maximum values between midday and late afternoon before declining toward the evening and night periods. This behaviour reflects the dominant influence of solar radiation on surface heating and boundary-layer development within the study area.

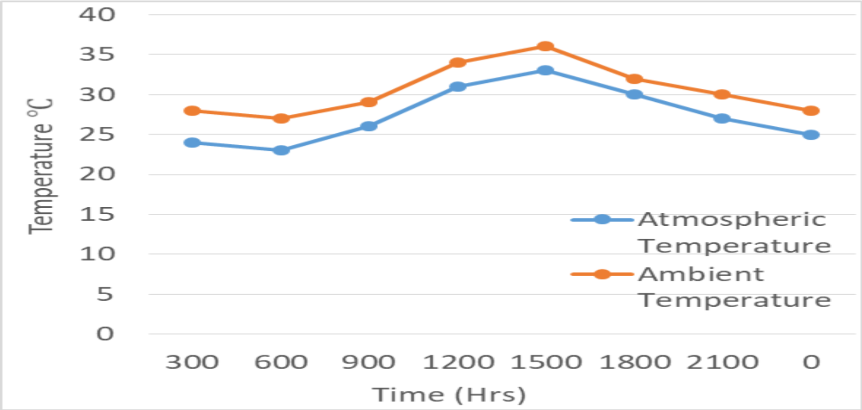

Figure 2: Variation of Atmospheric and Ambient Temperature with Time for Precipitation Possibilities

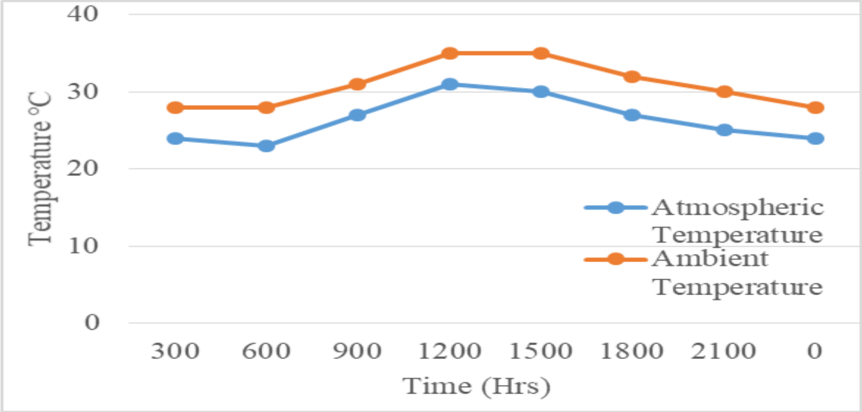

Figure 3: Variation of Atmospheric and Ambient Temperature with Time for Precipitation Possibilities

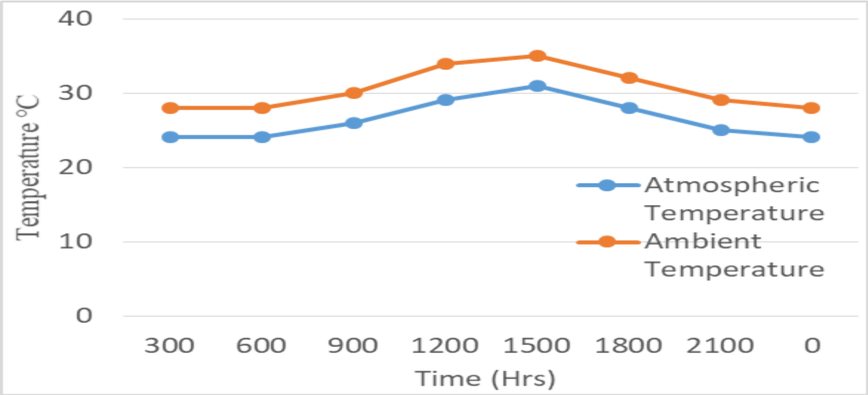

Figure 4: Variation of Atmospheric and Ambient Temperature with Time for Precipitation Possibilities

In Figure 2, atmospheric temperature increased from 23°C during the early morning period to a peak value of 33°C at 1500 h, while ambient temperature simultaneously increased from 27–28°C to approximately 36°C. Despite these elevated temperatures, precipitation probability remained negligible until the late afternoon period. A noticeable increase in rainfall likelihood occurred after 1500 h, reaching approximately 65% at 1800 h before decreasing later in the evening. The delayed rainfall response relative to maximum temperature suggests that atmospheric heating alone was insufficient to trigger precipitation immediately as reported by Song et al. (2025). Instead, sufficient time was required for moisture accumulation, cloud growth, and convective instability to develop within the lower atmosphere. A similar pattern is evident in Figure 3**,** although the precipitation response was considerably stronger. Atmospheric temperature reached its maximum value near midday before gradually declining, whereas precipitation probability increased sharply from 50% at 1200 h to approximately 95% at 1800 h. The rapid increase in rainfall probability indicates enhanced atmospheric instability and greater moisture availability compared with the conditions observed in Figure 2 (Cui et al., 2022). The pronounced separation between temperature maxima and rainfall peaks demonstrates that convective precipitation formation was governed by a combination of thermal forcing and delayed moisture convergence rather than instantaneous temperature changes. The atmospheric behaviour observed in Figure 4 further confirms the persistence of this diurnal climatic structure. Both atmospheric and ambient temperatures followed a consistent warming–cooling sequence throughout the day, while precipitation probability remained moderate and relatively stable, ranging between 15% and 40%. Unlike the previous cases, rainfall likelihood increased more gradually, suggesting weaker convective development and a comparatively stable atmospheric environment. Nevertheless, the tendency for rainfall probability to increase during the late afternoon and evening remained evident, reinforcing the importance of thermally induced convection in regulating precipitation occurrence within the region.

The consistency among the three figures indicates that temperature evolution constitutes a primary driver of rainfall development in Ado-Ekiti. Daytime heating enhances vertical instability and promotes upward transport of moisture, while subsequent cooling facilitates condensation and cloud maturation. The repeated occurrence of peak precipitation probability after maximum temperature conditions highlights the importance of temporal lag effects in tropical convective systems (Roca & Fiolleau, 2020). Such behaviour is characteristic of many tropical upland environments where local thermodynamic processes dominate rainfall generation.

From a health perspective, the observed temperature variability may influence human thermal comfort and physiological stress. Elevated afternoon temperatures can increase heat-related discomfort and dehydration risk, whereas increased evening humidity associated with rainfall development may contribute to conditions favourable for respiratory irritation and vector proliferation. Consequently, understanding the temporal behaviour of temperature provides valuable information for environmental health assessment and climate adaptation planning.

Diurnal Characteristics of Precipitation Probability

The temporal distribution of precipitation probability (PP) reveals a well-defined and recurring diurnal rainfall cycle throughout the study period. Although the magnitude of rainfall likelihood varied among the observation days, a common pattern emerged in which precipitation probability remained low during the morning hours and increased substantially during the late afternoon and evening periods. This behaviour reflects the influence of daytime surface heating, atmospheric moisture accumulation, and subsequent convective development (Alao et al., 2025). As shown in Figure 5, precipitation probability remained at or near zero between 0300 h and 1200 h, indicating relatively stable atmospheric conditions and limited convective activity during the morning period. Thereafter, PP increased progressively, reaching approximately 65% at 1800 h before declining to about 40% at 2100 h. This trend coincided with the gradual reduction in atmospheric and ambient temperatures observed after their daytime maxima, suggesting that rainfall development was associated with the delayed response of atmospheric moisture to cumulative daytime heating. The observed phase lag between peak temperature and peak precipitation supports the hypothesis that precipitation formation is controlled by thermodynamic processes involving evaporation, uplift, cooling, and condensation rather than instantaneous thermal conditions. A more pronounced precipitation response is evident in Figure 6, where PP increased from negligible morning values to approximately 95% by 1800 h and remained elevated throughout the evening period. The persistence of high precipitation probabilities indicates exceptionally favourable atmospheric conditions for convective rainfall formation. Such conditions are likely associated with enhanced moisture availability, stronger atmospheric instability, and more efficient vertical transport processes within the lower troposphere. Compared with Figure 5, the larger magnitude and longer duration of elevated PP suggest a more vigorous convective environment capable of sustaining precipitation-producing cloud systems over an extended period. In contrast, Figure 7 exhibits a comparatively moderate precipitation regime. Rainfall probability remained above zero throughout the observation period, fluctuating between approximately 15% and 40%. Rather than displaying a sharp evening maximum, PP increased gradually during the daytime and remained relatively stable thereafter. This behaviour suggests weaker convective forcing and reduced atmospheric instability compared with the conditions observed in Figure 6. The absence of a pronounced precipitation peak may indicate a more homogeneous atmospheric environment in which moisture availability and thermal gradients were insufficient to generate intense convective activity. In this perspective, the precipitation patterns observed across Figures 5–7 demonstrate a consistent inverse relationship between precipitation probability and daytime temperature maxima. In all cases, rainfall likelihood increased after the period of maximum atmospheric heating, confirming the existence of a temporal lag between thermal forcing and precipitation response. This relationship can be conceptually expressed in Equation 1:

$$PP(t) \propto f(T(t - \Delta t, q(t), w(t)) \quad (1)$$

Where Δt represents the lag between peak temperature and rainfall occurrence, q denotes atmospheric moisture content, and w represents vertical air motion. The recurring appearance of this lag across all datasets suggests that precipitation formation in the study area is predominantly controlled by localized convective processes driven by solar heating and moisture accumulation rather than by transient synoptic-scale disturbances.

The consistency of these precipitation dynamics has important implications for climate–health interactions. Elevated rainfall probabilities during the late afternoon and evening coincide with increased atmospheric humidity and reduced temperatures, conditions that may favour the proliferation of disease vectors and enhance the transmission of waterborne and respiratory illnesses (Casallas et al., 2026). Consequently, understanding the timing and magnitude of precipitation occurrence is essential for developing effective weather-informed public health interventions and improving local climate resilience strategies.

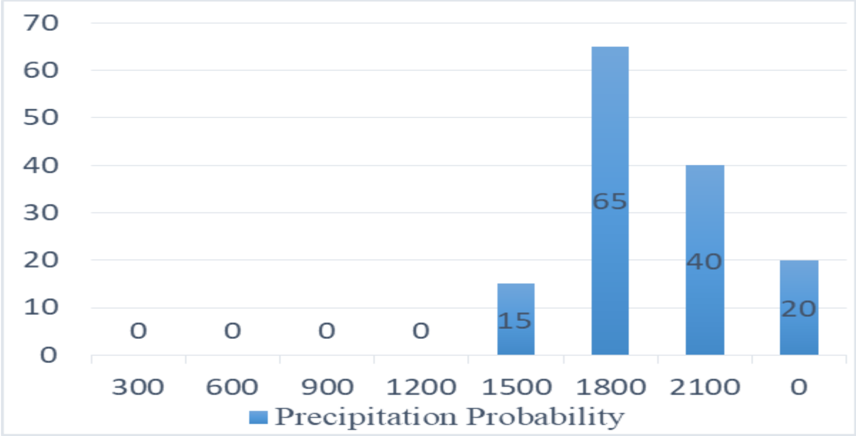

Figure 5: Variation of Precipitation Possibilities with Time

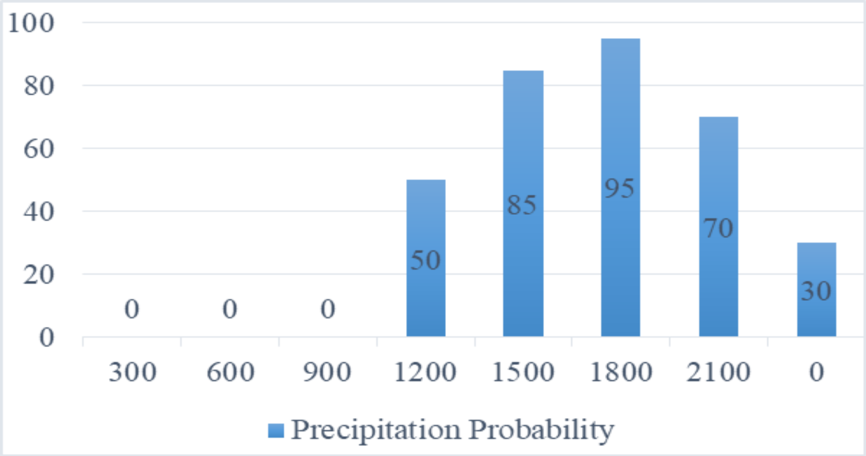

Figure 6: Variation of Precipitation Possibilities with Time

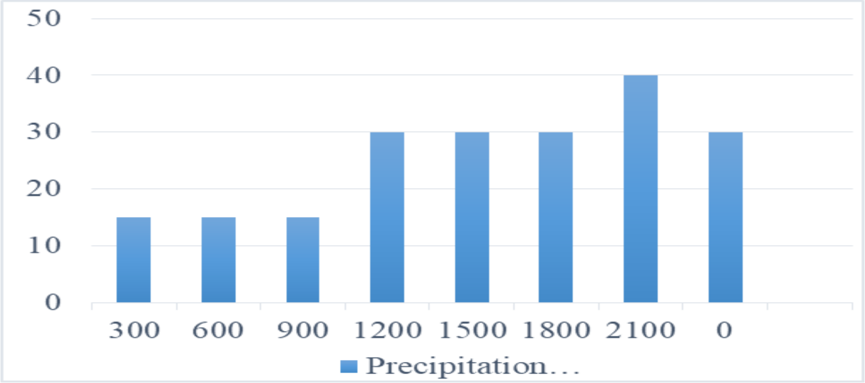

Figure 7: Variation of Precipitation Possibilities with Time

Wind-Speed Dynamics and Rainfall Development

Wind speed variability provides additional insight into the atmospheric conditions responsible for rainfall formation within the study area. Although wind intensity remained generally moderate throughout the observation period, temporal changes in wind behaviour were closely associated with variations in precipitation probability.

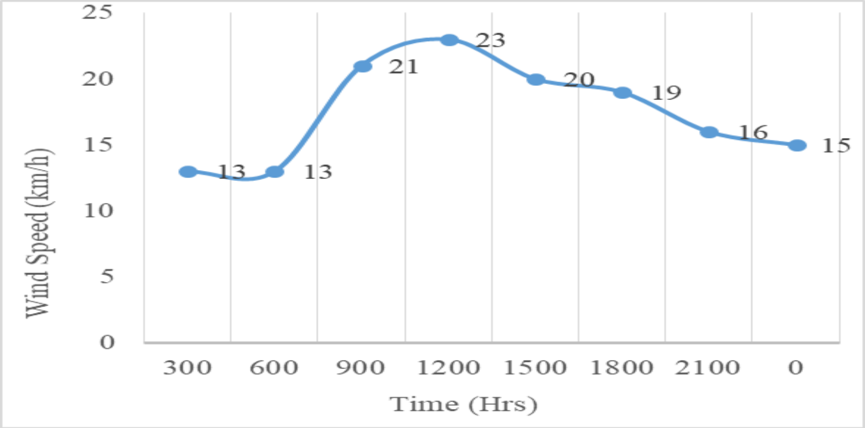

Figure 8: Variation of Wind Speed with Time for Precipitation Possibilities

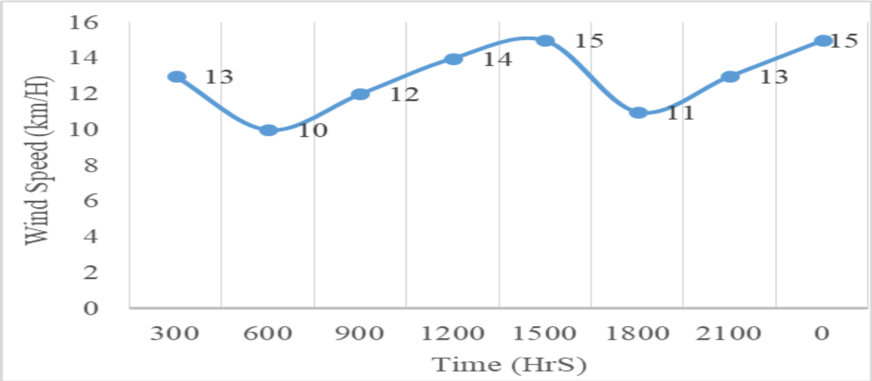

Figure 9: Variation of Wind Speed with Time for Precipitation Possibilities

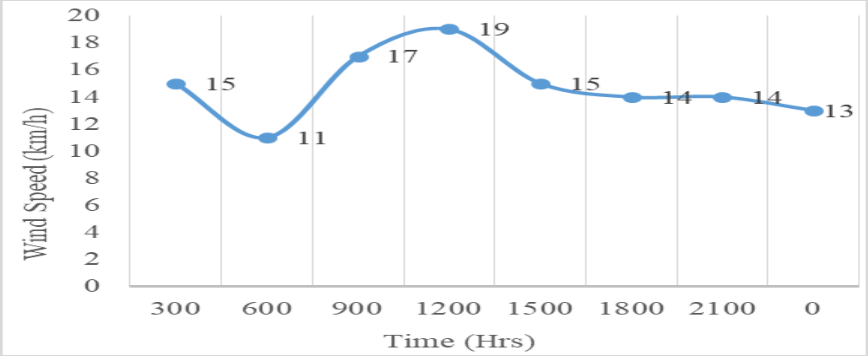

Figure 10: Variation of Wind Speed with Time for Precipitation Possibilities

In Figure 8**,** wind speed increased from approximately 13 km h^{-1} during the early morning period to a maximum value of 23 km h^{-1} around midday before gradually decreasing toward the evening. This pattern coincided with a substantial increase in precipitation probability during the late afternoon and early evening hours. The daytime strengthening of airflow likely enhanced horizontal moisture transport and atmospheric mixing, thereby contributing to the development of convective clouds and subsequent rainfall. The pattern observed in Figure 9 differs slightly from that of Figure 8. Wind speed fluctuated within a relatively narrow range of approximately 10–15 km h^{-1} throughout the day, yet precipitation probability increased dramatically from near-zero values during the morning to approximately 95% by 1800 h. This observation suggests that strong wind enhancement was not a prerequisite for rainfall development, this finding is consistent with Olson et al. (2019). Instead, atmospheric instability generated through surface heating and moisture accumulation appears to have provided sufficient energy to support convective precipitation (Liu et al., 2020). Figure 10 presents an intermediate situation in which wind speed increased moderately during the daytime before declining gradually after sunset. Rainfall probability simultaneously increased from approximately 15% during the early morning period to 40% by the evening. The concurrent evolution of temperature, wind speed, and precipitation probability indicates that local atmospheric circulation and thermodynamic processes acted together to support rainfall formation (da Silva et al., 2019). Furthermore, the wind-speed analysis reveals that moderate airflow contributes to rainfall generation primarily through moisture redistribution and atmospheric mixing rather than through direct dynamic forcing. The absence of exceptionally strong wind conditions throughout the observation period indicates that precipitation events in Ado-Ekiti were largely associated with localized convective mechanisms and terrain-modified atmospheric processes rather than severe synoptic-scale disturbances.

The elevated terrain surrounding the study area likely enhanced these effects by modifying airflow pathways and promoting localized uplift. Consequently, the interaction between topography, thermal instability, and moderate wind circulation represents an important mechanism controlling rainfall variability within the region.

Atmospheric–Environmental Interactions and Health Implications

The integrated analysis of temperature, wind speed, and precipitation probability demonstrates a strong coupling between atmospheric processes and environmental conditions in Ado-Ekiti. Temperature increases during the daytime promote atmospheric instability, while moderate wind circulation facilitates moisture transport and vertical mixing. These processes collectively contribute to cloud formation and rainfall occurrence, particularly during the late afternoon and evening periods. Furthermore, the elevated terrain of the study area enhances uplift mechanisms, increasing the likelihood of condensation and precipitation development.

The observed climatic variability has important implications for environmental sustainability and public health. Periods characterized by elevated precipitation probability may increase the risk of localized flooding, soil erosion, and deterioration of water quality (Chukwuma, 2025). Such conditions frequently create favourable environments for the transmission of waterborne diseases and sanitation-related illnesses. Conversely, prolonged periods of reduced rainfall and elevated temperature may contribute to heat stress, dehydration, reduced water availability, and associated socio-economic challenges.

The recurrent occurrence of high afternoon temperatures also has implications for human thermal comfort and occupational productivity, particularly among outdoor workers and vulnerable populations. Increased humidity during evening rainfall periods may further influence respiratory health and the survival of disease vectors. Therefore, the relationships identified among atmospheric variables extend beyond meteorological significance and provide valuable information for climate-sensitive health management and environmental planning.

The results highlight the need for integrated monitoring systems capable of linking meteorological observations with public-health surveillance. Such an approach would improve preparedness for weather-related hazards and strengthen adaptation strategies within climatically vulnerable upland communities.

CONCLUSION

This study investigated the temporal behaviour of atmospheric temperature, ambient temperature, wind speed, and precipitation probability under contrasting atmospheric conditions in Ado-Ekiti, Southwestern Nigeria. The analysis revealed a consistent diurnal pattern characterized by progressive daytime warming followed by evening cooling across all observation periods. Rainfall probability exhibited a delayed response relative to peak temperature conditions, with maximum values occurring predominantly during the late afternoon and evening hours. This temporal lag indicates that precipitation development is strongly influenced by the gradual evolution of atmospheric instability and moisture accumulation following daytime surface heating. Wind speed remained within a moderate range throughout the study period and displayed only limited variability. Although airflow contributed to moisture transport and atmospheric mixing, the results suggest that rainfall formation was controlled primarily by localized thermodynamic processes and terrain-induced atmospheric modification rather than strong synoptic-scale forcing. The persistence of similar temperature–precipitation relationships across multiple datasets demonstrates the relative stability of the climatic processes governing rainfall occurrence in the study area. The findings further reveal the importance of topographic influences in enhancing atmospheric uplift and supporting convective precipitation development. These interactions between thermal conditions, airflow dynamics, and terrain characteristics collectively determine rainfall variability within the upland environment of Ado-Ekiti. From an environmental and public-health perspective, the observed climatic behaviour has important implications for flood risk, water-resource availability, thermal stress exposure, and climate-sensitive disease occurrence. Integrating meteorological monitoring with environmental management and health-planning frameworks will therefore be essential for strengthening resilience to future climatic variability.

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