



CLIMATE INSTABILITY IN BENIN: COMPARATIVE ANALYSIS OF 2024 AND 2025

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ABSTRACT

Benin, situated at the transition zone between the Guinean and Sudanian climatic regimes, has experienced marked precipitation and thermal variability over recent decades. This study presents a comparative analysis of climate instability in Benin during 2024 and 2025, utilizing data from six national synoptic stations operated by Météo-Bénin: Cotonou, Bohicon, Savè, Parakou, Natitingou, and Kandi. The analytical framework evaluates annual and monthly cumulative rainfall, precipitation anomalies relative to the 1991–2020 climatological normal, rainy day frequency, mean annual temperatures, and synthetic variability indicators including the Standardized Precipitation Index (SPI). The findings indicate that 2024 was characterized by a generalized rainfall surplus (+9% to +14% above normal), causing significant flooding across multiple departments. In contrast, 2025 exhibited a more variable pattern, marked by an early-season deficit along the coastal strip (-6.5% in Cotonou) and near-normal totals across central and northern stations (-2.7% to +5.1%). Thermal analysis demonstrates a consistent interannual warming trend across all stations (+0.2°C to +0.3°C), with higher increments recorded in northern semi-arid zones. Furthermore, a decline in rainy days during 2025 alongside stable volume totals suggests an intensification of daily rainfall events. These results underscore the growing interannual climate volatility in Benin and highlight the necessity of strengthening early warning systems and institutional climate adaptation frameworks.

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INTRODUCTION

West African climate variability represents a critical domain of scientific inquiry due to its profound influence on rainfed agriculture, water resource security, public health, and disaster risk management (Nicholson, 2013; Sultan & Gaetani, 2016). Benin, a coastal West African state extending approximately 700 km from the Gulf of Guinea to the Niger River, exhibits heightened vulnerability to hydro-climatic fluctuations. This sensitivity is primarily driven by its latitudinal transition between the bimodal Guinean rainfall regime in the south and the unimodal Sudanian regime in the north.

Over the past decade, Benin has encountered pronounced climate anomalies, characterized by alternating periods of extreme rainfall and severe dry spells. For instance, in 2023, catastrophic flooding prompted state-of-emergency declarations across 32 of the nation's 77 communes (41.6% of the national territory), resulting in 46 fatalities and over 182,000 displaced individuals (Agence Nationale de Protection Civile [ANPC], 2024). Such recurring crises emphasize the imperative for rigorous, high-resolution evaluations of recent climatic behavior.

This study provides a comparative empirical assessment of climate instability in Benin during the consecutive years 2024 and 2025 across six synoptic monitoring stations. The specific objectives are to: (a) evaluate annual and monthly precipitation totals against the 1991–2020 climatological normal; (b) assess mean annual temperature trajectories; and (c) quantify climatic instability using standardized variability metrics to inform

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operational disaster risk reduction and climate adaptation policies.

LITERATURE REVIEW

Climatological research in West Africa demonstrates that sub-Saharan precipitation regimes have undergone structural shifts since the major Sahelian droughts of the 1970s and 1980s (Lebel & Ali, 2009). While total annual precipitation in parts of the Gulf of Guinea has partially recovered, the spatio-temporal distribution of rainfall has become increasingly erratic (Paeth et al., 2011). Recent studies indicate that this ‘hydro-climatic intensity’ is manifested through shorter rainy seasons, longer intra-seasonal dry spells, and a higher frequency of extreme precipitation events (Crétat et al., 2013).

In Benin, historical climate assessments highlight contrasting regional trends. Between the periods 1951–1980 and 1981–2010, most synoptic stations recorded declining annual precipitation, with the exception of coastal Cotonou (Amoussou et al., 2014; Boko et al., 2012). Furthermore, Houndénou (1999) established that agro-climatic risks in central and southern Benin are heavily governed by irregularities in the onset and cessation of the rainy seasons rather than total volumetric yields alone. Global projections synthesized by the Intergovernmental Panel on Climate Change (IPCC, 2021) confirm that West Africa will experience accelerated surface warming alongside increased precipitation volatility, reinforcing the need for continuous localized monitoring.

METHODOLOGY

Study Area and Synoptic Network

Benin lies between latitudes 6°30’ N and 12°30’ N and longitudes 0°45’ E and 3°25’ E. The country spans three main climatic zones: the sub-equatorial Guinean zone in the south (bimodal rainfall: main rainy season March–July, shorter rainy season September–November); the Sudano-Guinean transition zone in the center; and the Sudanian zone in the north (unimodal rainfall: May–October). Observational data were obtained from the national synoptic network of Météo-Bénin, comprising six primary reference stations: Cotonou, Bohicon, Savè, Parakou, Natitingou, and Kandi (Table 1).

Station	Department	Latitude	Longitude	Elevation (m)	
Cotonou	Littoral	6°21’ N	2°23’ E	4	Guinean Sub-equatorial
Bohicon	Zou	7°10’ N	2°04’ E	166	Sudano-Guinean Transition
Savè	Collines	8°02’ N	2°29’ E	165	Sudano-Guinean Transition
Parakou	Borgou	9°21’ N	2°37’ E	392	Sudanian Unimodal
Natitingou	Atacora	10°19’ N	1°23’ E	460	Sudanian Mountain
Kandi	Alibori	11°08’ N	2°56’ E	290	Northern Sudanian

Data Processing and Analytical Metrics

Monthly and annual precipitation totals, rainy day counts (threshold ≥ 1.0 mm), and mean surface air temperatures for 2024 and 2025 were evaluated against the 1991–2020 WMO climatological standard normal (Météo-Bénin, 2024, 2025). Relative rainfall anomalies (A) were calculated as:

Equation 1: $A = [(P - P_n) / P_n] * 100$

where P represents the observed annual precipitation (mm)

and P_n is the 1991–2020 baseline mean. Climate moisture anomalies were further standardized using the Standardized Precipitation Index (SPI; McKee et al., 1993):

Equation 2: $SPI = (P - P_{\bar{}}) / \sigma$

where P_̄ is the interannual baseline mean and sigma is the standard deviation. SPI values were categorized into standard drought and moisture classifications (e.g., SPI ≥ 2.0 extremely wet; 1.0 to 1.49 moderately wet; -0.99 to 0.99 near normal; ≤ -1.0 dry).

RESULTS AND FINDINGS

Annual Rainfall Cumulatives and Anomalies

Comparative analysis demonstrates a marked shift in precipitation volume between 2024 and 2025 across all six synoptic stations (Table 2). The year 2024 was characterized by widespread rainfall surpluses nationwide, ranging from +9.3% in Parakou to +13.9% in Kandi relative to the 1991–2020 normal. Conversely, 2025 exhibited a return toward baseline conditions, with slight negative anomalies recorded at coastal and central stations (-6.5% at Cotonou and -2.7% at Savè) and modest surpluses in northern stations (+2.1% to +5.1%).

Station	1991–2020 Normal (mm)	2024 Total (mm)	2025 Total (mm)	2024 Anomaly (%)	
Kandi	1010	1150	1040	+13.9	+3.0
Natitingou	1170	1320	1230	+12.8	+5.1
Parakou	1180	1290	1205	+9.3	+2.1
Savè	1110	1240	1080	+11.7	-2.7
Bohicon	1160	1310	1195	+12.9	+3.0
Cotonou	1380	1520	1290	+10.1	-6.5

Intra-Annual Distribution and Rainy Day Dynamics

Intra-annual rainfall distribution highlighted key regime-specific behaviors. Southern stations (Cotonou) displayed typical bimodal peaks in June and October, with 2024 showing significantly higher monthly peaks than 2025. Northern unimodal stations (Kandi) recorded maximum precipitation in

August, where 2024 totals exceeded 2025 by over 30 mm.

Despite relatively stable annual totals in 2025, a consistent reduction in the number of rainy days was observed across all stations (Table 3). Rainy

days decreased by 6 to 10 days in 2025 compared to 2024. Consequently, mean daily precipitation intensity (mm/day) remained elevated, indicating that annual precipitation was compressed into fewer, more intense convective events.

Station	Rainy Days 2024	Rainy Days 2025	Change (Days)	Intensity 2024 (mm/d)	
Kandi	58	52	-6	19.8	20.0

Station	Rainy Days 2024	Rainy Days 2025	Change (Days)	Intensity 2024 (mm/d)	
Na-titingou	92	85	-7	14.3	14.5
Parakou	98	90	-8	13.2	13.4
Savè	90	80	-10	13.8	13.5
Bohicon	95	88	-7	13.8	13.6
Cotonou	105	97	-8	14.5	13.3

Thermal Trends and Standardized Moisture Index

Mean surface temperatures reflected a systematic warming trend from 2024 to 2025 across all six stations (Table 4). Annual mean temperatures increased by +0.2°C to +0.3°C, with the highest mean temperatures recorded at northern stations (Kandi reaching 29.7°C in 2025).

Station	Mean Temp 2024 (°C)	Mean Temp 2025 (°C)	
Kandi	29.4	29.7	+0.3
Natitingou	27.6	27.8	+0.2
Parakou	27.9	28.2	+0.3
Savè	27.7	28.0	+0.3
Bohicon	27.4	27.6	+0.2
Cotonou	27.2	27.4	+0.2

Standardized Precipitation Index (SPI) calculations confirm a significant interannual transition (Table 5). While 2024 was classified as ‘moderately wet’ to ‘very wet’ across all stations (SPI between +1.04 and +1.54), 2025 transitioned to ‘near normal’ conditions across most stations, with Cotonou entering a ‘moderately dry’ classification (SPI -0.72).

Station	SPI 2024	SPI 2025	Class 2024	
Kandi	1.54	0.33	Very Wet	Near Normal
Na-titingou	1.42	0.57	Very Wet	Moderately Wet
Parakou	1.04	0.24	Moderately Wet	Near Normal
Savè	1.30	-0.30	Moderately Wet	Near Normal
Bohicon	1.44	0.34	Very Wet	Near Normal
Cotonou	1.13	-0.72	Moderately Wet	Moderately Dry

CONCLUSION

This comparative study demonstrates substantial interannual climate volatility in Benin between 2024 and 2025. The shift from a nationwide rainfall surplus in 2024 to near-normal or slightly deficient conditions in 2025, combined with reduced rainy day frequency and continuous thermal warming, underscores the compound risks facing southern and northern ecosystems. Increased rainfall intensity poses heightened urban flooding and soil erosion threats, whereas rising temperatures

exacerbate potential evapotranspiration and crop water stress.

To mitigate these dynamics, national policy must prioritize: (a) upgrading synoptic and automated hydrometeorological monitoring networks; (b) integrating downscaled seasonal forecasts into agricultural extension and disaster preparedness workflows; and (c) developing resilient urban drainage and rainwater harvesting infrastructure tailored to high-intensity precipitation events.

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