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Climate Vulnerability and Local Response: An LVI-IPCC Assessment of the Climate Emergency in Gombe LGA, Gombe State, Nigeria

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Abstract

Climate change constitutes an escalating environmental and socio-economic emergency in semi-arid regions where livelihoods are intrinsically dependent on climate-sensitive natural resources. Gombe Local Government Area (LGA), Gombe State, northeastern Nigeria, exemplifies the combined impacts of rising temperatures, increasing rainfall variability, and ecological degradation, all of which intensify household vulnerability. This study employed the Livelihood Vulnerability Index (LVI) and its Intergovernmental Panel on Climate Change (IPCC)-aligned framework (LVI-IPCC) to quantify climate vulnerability and evaluate local adaptation responses. A mixed-methods approach integrated climatic trend analysis (1981–2025), a household survey of 400 randomly selected respondents across ten wards, 25 key informant interviews, and eight focus group discussions. Climatic analysis revealed a statistically significant warming trend of 0.28 °C per decade ($p < 0.01$), accompanied by increased rainfall variability (coefficient of variation = 24%) and a progressively shortening growing season. Household vulnerability was primarily driven by high climate exposure, particularly recurrent floods and droughts, and elevated sensitivity resulting from water insecurity (LVI component score = 0.672) and food insufficiency (0.588). Adaptive capacity remained constrained by limited household assets and weak institutional support systems. The composite LVI-IPCC score of 0.32 indicates moderate-to-high climate vulnerability, with Shamaki, Pantami, and Jekadafari wards identified as the most vulnerable. Local adaptation strategies were predominantly autonomous, including crop diversification (79%), livelihood diversification (72%), dry-season farming (41%), and migration (54%), although many households continued to adopt erosive coping mechanisms. Institutional responses remain fragmented, underfunded, and inadequately coordinated. The study recommends establishing a local climate desk, implementing community-based adaptation planning, integrating climate services into agricultural extension, and creating a dedicated local climate fund. The proposed framework provides a replicable methodology for sub-national climate vulnerability assessment and supports evidence-based implementation of Nigeria's Nationally Determined Contributions.

Keywords

Climate change;
Livelihood Vulnerability Index (LVI);
LVI-IPCC;
Climate adaptation;
Gombe State.

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1. Introduction

The semi-arid zones of West Africa are at the frontline of climate change. The Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report confirms that temperatures in the Sahel have risen by 0.2–0.5°C per decade since the 1970s, with projections of an additional 2.5–4.5°C warming by century's end under high-emission scenarios (IPCC, 2022). This warming, coupled with increasingly erratic rainfall patterns, directly threatens the livelihood foundations of millions of smallholder farmers and pastoralists (Sultan & Gaetani, 2016). Nigeria, Africa's most populous country, experiences severe climate vulnerability in its northern states, where the semi-arid ecology and rain-fed agriculture create a high sensitivity to climatic shocks (Odjugo, 2010; Abubakar et al., 2022).

Gombe State in northeastern Nigeria epitomizes these challenges. The state's economy is agrarian, with over 80% of its population relying on rain-fed crops and livestock (Gombe State Government, 2021). Recurrent flooding, droughts, and land degradation have undermined food security and displaced communities. The 2022 floods alone affected over 30,000 households across the state, highlighting the fragility of local institutional capacities (NEMA, 2022). Gombe Local Government Area (LGA), the state capital and a microcosm of the wider emergency, faces a confluence of flash floods, water scarcity, heat stress, and declining agricultural productivity. However, vulnerability assessments at the LGA scale remain sparse, with existing studies either narrowly focused on agricultural trends (Abba & Buba, 2019) or flood risk mapping (Mohammed & Adamu, 2021) without capturing the multidimensional lived experience of communities.

The concept of vulnerability has evolved from a hazard-centric perspective to a socially constructed understanding, where vulnerability is the product of exposure, sensitivity, and adaptive capacity (IPCC, 2014). The Livelihood Vulnerability Index (LVI), developed by Hahn et al. (2009), operationalises this multidimensional framework by integrating socio-demographic, livelihood, social network, health, food, water, and climate hazard indicators. Its adaptation to the IPCC framework (LVI-IPCC) enables quantification of the three contributing factors, providing a spatially explicit and comparative vulnerability profile (Antwi-Agyei et al., 2013). To date, no LGA-level application of this robust methodology exists in Gombe State.

Furthermore, while communities actively deploy autonomous adaptation strategies crop diversification, water harvesting, migration, and reliance on social networks the effectiveness and sustainability of these responses are increasingly challenged by the pace of climatic change (Nyong et al., 2007; Ajani et al., 2013). Planned institutional interventions remain disconnected from grassroots realities, creating an adaptation deficit (Burton, 2009). This study addresses these gaps by providing a rigorous, mixed-methods assessment of climate vulnerability and local responses in Gombe LGA, using the LVI-IPCC framework, with the aim of generating evidence to support targeted, sub-national climate governance.

The specific objectives are to: (1) analyze climatic trends (1981–2025); (2) examine

household perceptions of environmental change; (3) quantify livelihood vulnerability and map spatial differentials; (4) document adaptation strategies; (5) identify barriers to effective response; and (6) provide policy recommendations.

2. Methodology

2.1 Study Area

Gombe LGA lies in central Gombe State (10°15′–10°20′N, 11°08′–11°12′E), covering approximately 52 km². The climate is tropical wet and dry (Aw/Köppen) verging on semi-arid, with a mean annual temperature of 27.5°C and average rainfall of 850 mm, unimodal from May to October. The vegetation is Sudan savanna, heavily degraded by deforestation and agricultural expansion. Drainage occurs via seasonal streams (Gadum, Liji, Pantami) that are prone to flash flooding. The population is estimated at 350,000, predominantly Hausa-Fulani, and the economy relies on rain-fed farming (maize, sorghum, millet, cowpea) and livestock. Severe infrastructure deficits and low educational attainment compound socioeconomic vulnerability (Gombe State BOS, 2021).

2.2 Research Design and Sampling

A cross-sectional mixed-methods design was employed. Ten of the eleven wards were purposively selected to represent the heterogeneity of rural, peri-urban, and urban settings. Ajiya, Dawaki, Herwagana, Jekadafari, Kagarawal, Pantami, Shamaki, Bolari, Tudun Wada, and Wuro-Ladde. A stratified random sample of 400 households (40 per ward, stratified by livelihood orientation) was drawn, with sample size determined using Yamane's formula at 5% precision. Additionally, 25 key informant interviews (KIIs) were conducted with ward heads, government officials, extension agents, and CSO representatives, alongside eight gender-segregated focus group discussions (FGDs) of 8–12 participants each.

2.3 Data Collection

A structured household questionnaire (pre-tested) captured demographics, livelihood strategies, food security, water access, health, social networks, climate perceptions, adaptation practices, and barriers. KIIs explored institutional assessments, policies, and coordination. FGDs employed participatory tools (seasonal calendars, hazard timelines, ranking). Climatic data for 1981–2025 were sourced from the Nigerian Meteorological Agency (NiMet) and CHIRPS gridded datasets at 0.05° resolution.

2.4 Data Analysis

Climatic trends were analyzed using the Mann-Kendall test and Sen's slope estimator. the Standardized Precipitation Index (SPI-12) characterized drought. The LVI was calculated following Hahn et al. (2009), 35 indicators across seven major components Socio-Demographic Profile (SDP), Livelihood Strategies (LS), Social Networks (SN), Health (H), Food (F), Water (W), and Natural Hazards and Climate Variability (NHCV) were normalized to a 0–1 scale and aggregated. The LVI-IPCC was derived by assigning components to exposure (NHCV), sensitivity (SDP, H, F, W), and adaptive capacity (LS, SN), and calculating the product (exposure adaptive capacity) × sensitivity, rescaled to an approximate -1 to +1 range (Antwi-Agyei et al., 2013). Qualitative data underwent thematic content analysis using NVivo 12. Cronbach's alpha for LVI components ranged from 0.65 to 0.87, confirming acceptable internal consistency.

3. Results

3.1 Climatic Trends (1981–2025)

The annual mean temperature in Gombe LGA was 27.8°C (SD=0.65) and exhibited a statistically significant increasing trend ($Z=3.84$, $p<0.001$) of 0.028°C/year, equivalent to 0.28°C per decade (Table 1). Warming was more pronounced in the dry season (0.032°C/year) and minimum temperatures rose faster than maxima (0.031°C/year vs. 0.025°C/year). The frequency of hot days (Tmax >35°C) increased from 45 days/year in the 1980s to 72 days/year in the 2010s.

Annual rainfall averaged 854 mm (CV=24%), with a non-significant declining trend (-2.3 mm/year). However, the growing season shortened by 2.7 days per decade ($p<0.1$) due to later onset and earlier cessation. Dry spells within the growing season rose from an average of 2.1 to 3.5 spells per season. SPI-12 analysis revealed alternating severe droughts (1983, 2015–2018) and extreme wet events (1999, 2012, 2019), confirming a dual hazard environment.

Table 1: Climate Trend Statistics (Mann-Kendall and Sen's Slope)

Variable	MK-Z	p-value	Sen's Slope (unit/yr)	Trend
Annual Mean Temp (°C)	3.84	<0.001	0.028	Increasing
Min Temp (°C)	4.12	<0.001	0.031	Increasing
Annual Rainfall (mm)	-1.12	0.262	-2.31	Not significant
Growing Season Length	-	-	-2.7 days/decade	Shortening

$p<0.001$; $p<0.1$

3.2 Household Perceptions

Household awareness of climatic changes was acute and widespread (Table 2). A 91% majority perceived temperature increase, while 86% reported declining rainfall predictability. Environmental degradation was nearly universally recognized: 88% observed vegetation loss and 87% noted soil fertility decline. These perceptions aligned closely with instrumental climate data.

Table 2: Perceived Changes Over the Past 20 Years (N=400)

Perceived Change	Increased (%)	Decreased (%)	No Change/Don't Know (%)
Temperature	91.2	2.0	6.8
Rainfall predictability	2.5	86.0	11.5
Flood events	78.3	5.8	15.9
Drought/dry spells	65.0	8.0	27.0
Vegetation cover	4.0	88.5	7.5
Soil fertility	3.5	87.0	9.5

3.3 Livelihood Vulnerability Assessment

The aggregated LVI component scores revealed high sensitivity and exposure, with water (0.672) and natural hazards (0.654) the most vulnerable dimensions (Table 3). Food security scored 0.588, while health and socio-demographic profiles were moderate. Adaptive capacity components livelihood strategies (0.438) and social networks (0.395) were comparatively better but still indicated considerable fragility. The overall LVI for the LGA was 0.541 (moderate-high vulnerability).

Table 3: LVI Component Scores

Major Component	Score (0–1)	Vulnerability Level
Water	0.672	High
Natural Hazards & Climate Variability	0.654	High
Food	0.588	High

Health 0.531 Moderate-High
Socio-Demographic Profile 0.510 Moderate
Livelihood Strategies 0.438 Moderate
Social Networks 0.395 Moderate
Overall LVI 0.541 Moderate-High

Using the IPCC framework, the aggregated exposure score was 0.654, sensitivity 0.575, and adaptive capacity 0.417. The LVI-IPCC was 0.136 (rescaled to ~0.32 on a -1 to +1 scale), classifying Gombe LGA as moderate-high vulnerability, driven by the gap between high exposure and insufficient adaptive capacity, amplified by sensitivity.

Ward level analysis revealed significant spatial disparities. Shamaki (0.230 raw score), Pantami (0.189), and Jekadafari (0.162) were the most vulnerable, while more urbanized wards like Ajiya (0.048) and Tudun Wada (0.039) recorded the lowest vulnerability. High-vulnerability wards are characterized by dense peri-urban settlements, riverine exposure, poor water and sanitation infrastructure, and higher concentrations of poor, migrant, and female-headed households.

3.4 Local Response Mechanisms

Household adaptation is predominantly autonomous (Table 4). Crop diversification (79% of farming households) and livelihood diversification (72%) were the most widespread strategies. Dry-season farming (41%) and water harvesting (28%) had moderate uptake. Migration was a key strategy for 54% of households, predominantly to southern Nigerian cities. However, erosive coping was alarmingly common: 62% reduced meal frequency during food shortages, 48% borrowed at high interest, 23% sold productive assets, and 15% withdrew children from school.

Table 4: Key Adaptation Practices and Uptake Rates (Farming Households)

Practice	Adoption Rate (%)
Crop diversification	79
Livelihood diversification	72
Migration (seasonal/permanent)	54
Dry-season farming	41
Water harvesting	28
Erosive coping (meal reduction)	62

Community-based strategies, including labour-sharing groups (gayya), communal grain banks, and zakat (charitable giving), persist but are declining under repeated shocks and social change. Formal institutional responses are minimal: only 12% of farmers received early warning information from extension services, and the extension agent-to-farmer ratio exceeds 1:5,000. Post-disaster relief by NEMA/SEMA is reactive, under-resourced, and affected by poor coordination. No dedicated LGA climate desk or climate budget line exists.

3.5 Barriers to Adaptation

Thematic analysis identified six interrelated barriers: (1) financial constraints (84% of respondents cited lack of capital); (2) information deficit (dysfunctional extension, non-localized advisories); (3) institutional failure (fragmentation, elite capture, corruption); (4) infrastructure deficit (roads, irrigation, electricity); (5) insecure land tenure (especially for women and migrants); and (6) ecological limits (groundwater depletion, deforestation).

4. Discussion

4.1 Climate Change as a Lived Emergency

The observed warming of 0.28°C/decade aligns with Sahel-wide estimates (Niang et al., 2014)

and confirms that Gombe LGA is fully embedded in regional warming. The faster increase in minimum temperatures and the rising frequency of hot days have direct agronomic implications: higher night respiration reduces grain yields, while heat stress affects both crops and livestock (Lobell et al., 2011).

The non-significant decline in total rainfall masks a critical shift towards greater intra-seasonal variability shorter, more intense rain events interspersed with longer dry spells consistent with the "it never rains but it pours" pattern observed across the Sahel (Nicholson, 2013). This dual flood-drought dynamic creates a whiplash effect, depleting household buffers and complicating adaptation planning. The high convergence between instrumental data and local perceptions (over 90% awareness) reinforces the urgency for interventions that build on this experiential knowledge, as suggested by Mertz et al. (2012).

4.2 The Anatomy of Vulnerability

The LVI-IPCC results reveal that vulnerability in Gombe LGA is not solely a function of climatic exposure but is structurally rooted in high sensitivity, particularly water insecurity and food insufficiency. The water component score (0.672) is among the highest reported in similar semi-arid contexts (Belay et al., 2017), reflecting heavy reliance on unimproved sources and the failure of shallow wells during extended dry seasons. This directly undermines health, agricultural productivity, and women's time burdens, reinforcing poverty traps.

Food sensitivity is driven by the predominance of rain-fed agriculture with minimal inputs and limited crop diversity, resulting in chronic "hunger seasons" of 2–4 months. This structural food deficit perpetuates malnutrition and forces households into adverse coping. The moderate adaptive capacity score (0.417) is deceptive: while social networks provide a crucial safety net, qualitative evidence suggests these are eroding under the strain of repeated shocks, monetization of reciprocity, and the influx of internally displaced persons (IDPs).

Livelihood diversification often represents "coping diversification" rather than accumulation, trapping households in low-return informal activities (Ellis, 1998). The spatial variation in vulnerability underscores climate injustice: the most marginalized wards bear the greatest burden, a pattern that the Pressure and Release (PAR) model explains through the cumulative effect of root causes (marginalization, tenure insecurity) and dynamic pressures (unplanned settlement, deforestation) producing unsafe conditions (Wisner et al., 2004).

4.3 Local Responses and the Limits of Autonomous Adaptation

Households are active agents, not passive victims. Crop diversification and dry-season farming represent positive adaptive strategies with potential for scaling if supported by improved inputs and secure water access. However, the high prevalence of erosive coping asset sales, meal reduction, school withdrawal indicates that for a significant segment of the population, adaptive capacity is already exhausted. This aligns with the concept of the adaptation deficit, where current responses are insufficient to protect future well-being (Burton, 2009). The reliance on migration as a strategy is ambiguous: while remittances

stabilize consumption, distress migration can deplete household labour and expose migrants to urban vulnerabilities. The decline of traditional communal safety nets (e.g., gayya, grain banks) reflects broader socio-economic transformations observed across the Sahel, which erode collective resilience (Raynaut, 2001).

4.4 Institutional Dysfunction and the Governance Gap

The near-absence of planned adaptation in Gombe LGA mirrors a systemic failure of climate governance at the sub-national level in Nigeria. Despite national policy frameworks and NDC commitments, the translation to local action is stymied by fragmented coordination, chronic underfunding, and the lack of a dedicated institutional mechanism. The 12% reach of early warning information exemplifies the usability gap in climate services (Lemos et al., 2012), where technical forecasts fail to be translated into actionable, last-mile advisories due to weak extension systems.

Without complementary investments in inputs and infrastructure, climate information alone cannot induce adaptation. Elite capture and the spatial mismatch of donor projects further marginalize vulnerable communities. The findings strongly support the call for integrated, community driven adaptation planning that addresses both the proximate and structural drivers of vulnerability, including land tenure reform and inclusive governance (Eriksen et al., 2015; Dazé & Echeverría, 2020).

5. Conclusion and Recommendations

This study provides the first empirical, mixed-methods vulnerability assessment at the LGA scale in Gombe State, demonstrating the utility of the LVI-IPCC framework for generating spatially explicit, policy-relevant evidence. The climate emergency in Gombe LGA is a lived reality of rising temperatures, erratic rainfall, and severe environmental degradation. Livelihood vulnerability is high, driven by water and food insecurity, while adaptive capacity remains fragile and insufficient to offset exposure. Households deploy diverse autonomous responses, but a substantial proportion resort to erosive coping, indicating that resilience thresholds are being breached. The failure of institutional planned adaptation perpetuates a governance gap that must be urgently addressed.

To transition from reactive coping to proactive resilience, the following recommendations are proposed:

1. **Institutionalize local climate governance:** Establish a Gombe LGA Climate Desk and multi-stakeholder platform to coordinate, plan, and monitor climate action, with a ring-fenced budget of at least 2% of annual LGA expenditure.
2. **Develop and fund a Local Climate Action Plan (LCAP):** Aligned with the state development agenda and Nigeria's NDC, the plan should prioritize investments based on vulnerability maps.
3. **Invest in last-mile climate services:** Operationalize a system to deliver downscaled, local-language seasonal forecasts and early warnings through radio, SMS, and extension agents; urgently improve the extension agent-to-farmer ratio.
4. **Prioritize water and food security:** Scale up solar-powered boreholes, rainwater harvesting, small-scale irrigation, and community seed banks for drought-tolerant varieties; promote agroforestry for soil restoration.

5. Strengthen institutional accountability and tenure: Clarify agency roles, establish a transparent state climate fund, and facilitate pro-poor land tenure reforms, especially for women and migrant farmers.

6. Scale up community-based adaptation: Target high-vulnerability wards with community-managed micro-projects and revitalize traditional safety nets through linkages with micro finance.

Study Limitations

This study was limited to vulnerable people of Gombe Local Government Area of Gombe State. Consequently, the findings should be interpreted within the context of the study area and may not necessarily represent all ward or communities in Nigeria. In addition, the study relied primarily on self-reported questionnaire responses, which may be subject to response bias. Future studies employing mixed-methods approaches and broader geographical coverage may provide more comprehensive evidence regarding climate vulnerability and local response for livelihood in Gombe state.

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Conflict of Interest

The authors declare that there are no financial, personal, or institutional conflicts of interest that could have influenced the conduct, analysis, or reporting of this research.

Ethical Considerations

Prior to fieldwork, ethical clearance was granted by the appropriate institutional ethics committee. The study adhered strictly to established ethical protocols. All participation was voluntary, and informed consent was duly obtained from each respondent. To protect participants rights, strict measures were implemented to ensure the confidentiality and anonymity of all data provided. Respondents were explicitly informed that the information collected would be utilized solely for scholarly and research purposes.

Data Availability Statement

The datasets supporting this study's findings are accessible from the corresponding author upon reasonable request.

Author Contributions

Abdulmusauwir Aminu Ahmad: Conceptualization, methodology, investigation, data collection, formal analysis, interpretation of results, writing original draft preparation, and manuscript revision.

Prof. A. U. Faruk: Supervision, methodology, critical review of the manuscript, validation of results, and academic guidance.

Prof. I. Y. Chindo: Supervision, conceptual guidance, manuscript review and editing, interpretation of findings, and final approval of the manuscript for submission.

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