

Climate Vulnerability and Rural Livelihoods in the Agroecological Zones of Taraba State, Nigeria

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Abstract

Climate change poses a significant threat to rural livelihoods, particularly in ecologically diverse and socioeconomically fragile regions like Taraba State, Nigeria. This study assesses the spatial patterns of climate vulnerability across the state's four main agroecological zones: Montane, Southern Guinea Savannah, Northern Guinea Savannah, and Sudan Savannah. Using the IPCC vulnerability assessment framework focusing on exposure, sensitivity, and adaptive capacity, a mixed-methods approach was adopted, combining geospatial data, household surveys, and statistical analyses. Findings revealed that all zones are moderately to highly vulnerable, with the Northern Savannah zone identified as the most vulnerable due to high exposure to rural heat and windstorms, combined with weak adaptive capacity. Flooding emerged as the most significant climate hazard across zones, followed by rural heat and windstorms, while drought was perceived as less impactful. Socioeconomic factors such as low literacy, limited healthcare access, poor infrastructure, and inadequate insurance coverage were found to exacerbate vulnerability. While indigenous coping strategies exist, they are often insufficient in the face of increasing climate extremes. The study emphasizes the need for zone-specific adaptation strategies, improved rural infrastructure, ecosystem-based adaptation, and increased support for vulnerable groups such as women and youth. By offering a nuanced understanding of climate risk at the sub-regional level, this study provides a valuable evidence base for targeted interventions and climate-resilient rural development in Nigeria. It contributes to bridging the knowledge gap on localized climate impacts and supports the formulation of more effective, context-specific adaptation policies in vulnerable rural settings.

Keywords: Adaptation Strategies, Agroecological Zones, Climate Vulnerability, Rural Livelihoods and Taraba State

Introduction

Climate change is increasingly recognized as one of the most pressing global challenges, with severe implications for ecosystems, economies, and human well-being. In sub-Saharan Africa, the impacts are disproportionately felt by rural communities whose livelihoods are intricately linked to natural resources and agroecological systems. Nigeria, the most populous country in Africa, exemplifies this vulnerability, particularly in its northeastern region where climatic variability and socioeconomic fragility intersect to exacerbate risks to rural livelihoods (Adefolalu, 2007; NIMET, 2020).

Taraba State, located in northeastern Nigeria, presents a diverse range of agroecological zones, including lowland savannas, floodplains, and the montane ecosystems of the Mambilla Plateau. This ecological heterogeneity creates varying degrees of climate exposure across the state. The rural communities inhabiting these zones are increasingly exposed to a complex array of climate-related hazards such as prolonged dry spells, erratic rainfall, rising temperatures, floods, and landslides (NIMET, 2020). The montane regions, for instance, experience frequent landslides and soil erosion during the rainy season due to intense rainfall combined with steep topography and unsustainable

land-use practices. Conversely, lowland zones are prone to seasonal floods that disrupt farming and displace settlements, while periodic droughts reduce crop yields and water availability.

The sensitivity of these rural communities to climate impacts is largely a function of their socioeconomic conditions and environmental dependencies. Agriculture, the dominant economic activity in Taraba State, is predominantly rain-fed and highly susceptible to climatic fluctuations. Crops such as maize, yam, millet, and tea are grown with minimal irrigation and technological input, making them vulnerable to water stress and temperature extremes. Livestock rearing, fishing, and collection of non-timber forest products also form essential parts of rural livelihoods but are similarly exposed to the vagaries of the climate (Fagbemi & Olorunfemi, 2019). Environmental degradation, poor land-use planning, and deforestation have further increased the sensitivity of ecosystems, undermining the ability of communities to sustain traditional livelihood practices.

Adaptive capacity, which determines the ability of communities to respond to and recover from climate shocks, remains critically low in many parts of Taraba State. Constraining factors include widespread poverty, weak infrastructure, limited access to agricultural extension services, inadequate education, poor health facilities, and gender-based inequalities in resource access and decision-making (IFAD, 2021; Eze et al., 2019). Although local knowledge systems, such as indigenous weather forecasting and adaptive farming techniques, offer some resilience, these are often overwhelmed by the increasing intensity and unpredictability of climate events. Additionally, the lack of government support, absence of comprehensive climate policies at the local level, and minimal integration of climate risk management into rural development plans further inhibit adaptation.

The cumulative effects of these vulnerabilities manifest profoundly in the livelihoods and well-being of rural households. Climate variability disrupts agricultural calendars, reduces yields, and increases food insecurity, particularly during lean seasons. Income losses force households to adopt adverse coping strategies such as distress migration, child labor, and over-extraction of natural resources, which in turn deepen environmental degradation and social inequities (Eze et al., 2019). Women and youth, who often have fewer assets and decision-making power, are especially affected, experiencing heightened food insecurity and reduced opportunities for education and economic participation.

Furthermore, the socio-psychological burden of climate change manifested through anxiety, uncertainty, and inter-community conflict over land and water resources is becoming increasingly evident. For instance, clashes between farmers and pastoralists, often attributed to land scarcity and changing weather patterns, have escalated in parts of Taraba, undermining social cohesion and community resilience. Thus, climate vulnerability in these agroecological zones is not merely an environmental concern, but a multidimensional development challenge affecting the most fundamental aspects of rural life: food, water, income, health, and social stability.

Given these complexities, this study seeks to investigate the differentiated climate vulnerabilities across the agroecological zones of Taraba State, Nigeria. It aims to assess: (1) the climate-related hazards affecting rural communities; (2) the socio-environmental sensitivity and adaptive capacity of households; and (3) the implications for rural livelihoods, food security, and well-being. By integrating geospatial analysis, household surveys, and participatory assessments, this research contributes to a nuanced understanding of climate vulnerability in a region that is both ecologically rich and socioeconomically fragile. The findings are expected to inform targeted policy interventions and adaptive strategies that enhance climate resilience, reduce poverty, and promote sustainable rural development in Nigeria's agroecological landscapes.

Statement of the Research Problem

Rural communities across Nigeria's agroecological zones are increasingly experiencing the adverse effects of climate change, yet the spatial and socioeconomic dimensions of their vulnerabilities remain poorly understood and insufficiently addressed. In Taraba State, a region of significant ecological diversity including lowland plains, river valleys, and montane ecosystems like the Mambilla Plateau, climate-related hazards are intensifying in frequency and impact. Communities in these zones face a complex array of climate exposures, including erratic rainfall patterns, prolonged droughts, increasing temperatures, soil erosion, floods, and landslides (NIMET, 2020). These hazards not only threaten environmental stability but also severely disrupt rural agricultural systems that are critical to livelihoods and food security.

Despite these challenges, there remains a lack of disaggregated data and nuanced understanding of how different agroecological zones respond to climate stressors. The sensitivity of rural livelihoods in Taraba State is heightened by heavy dependence on rain-fed subsistence agriculture, fragile infrastructure, poor land-use practices, and environmental degradation. Meanwhile, the adaptive capacity of communities is constrained by widespread poverty, limited access to extension services and climate information, low education levels, and weak institutional support systems (IFAD, 2021; Fagbemi & Olorunfemi, 2019). While indigenous coping mechanisms exist, they are often reactive and insufficient in the face of escalating and unpredictable climate risks.

The impacts on livelihoods and well-being are far-reaching. Declines in agricultural productivity due to shifting rainfall patterns and soil degradation have led to food insecurity, income loss, and increased livelihood diversification often into unsustainable or marginal activities (Eze et al., 2019). These outcomes disproportionately affect vulnerable groups such as women and youth, deepen existing inequalities, and contribute to rural-urban migration. Additionally, the social and psychological toll of climate stress manifested in inter-group conflicts, especially between farmers and herders over dwindling natural resources further undermines community resilience.

Existing studies on climate change in Nigeria often adopt national or regional scales, failing to capture the micro-level dynamics and spatial heterogeneities within agroecological zones like those in Taraba State. As a result, policy responses remain generalized and poorly targeted. There is a critical knowledge gap regarding the localized manifestations of climate vulnerability, how they interact with socioeconomic variables, and how they impact rural livelihoods in specific agroecological contexts.

This study, therefore, seeks to address these gaps by systematically examining the nature and extent of climate vulnerability in the agroecological zones of Taraba State. It focuses on identifying climate-related hazards, evaluating the sensitivity and adaptive capacity of rural communities, and assessing the impacts on livelihoods, food security, and well-being. The findings are expected to provide a robust empirical basis for designing targeted, context-specific adaptation strategies and policy interventions aimed at enhancing climate resilience and sustainable rural development.

Methodology

This study adopted a convergent mixed-methods approach to assess climate vulnerability and its impacts on rural livelihoods in montane ecosystems, integrating both quantitative and qualitative data collection and analysis. This design allowed for a comprehensive and triangulated understanding of the multidimensional challenges facing rural communities in highland regions. The methodology was structured around the Intergovernmental Panel on Climate Change (IPCC) vulnerability assessment framework, which conceptualizes vulnerability as a function of exposure, sensitivity, and adaptive capacity (IPCC, 2021).

The Population data 2006 for the area was projected to the year 2021 using the method of Mehta (2004). The method is presented as:

$$P_n = P_o (1 + R/100)^n \quad \text{-----} \rightarrow (1)$$

Where: P_n = Population in the current year

P_o = Population in the base year

R = Annual growth rate

n = Number of intermediary years

Based on the method above, the projected population of the study area for the year 2021 was 336,326. A sample size of 1066 household heads using a marginal error of 3% adopted from Saunders (1997) was employed to represent the sampled size.

Questionnaire was designed to capture all the selected indicators (exposure, sensitivity, and adaptive capacity) for the vulnerability index. These indicators were selected based on the fact that they could be easily obtained either by questionnaire or their availability in institutions and literatures (see Table 1). A five-point Likert Scale (LS) was used (strongly agree, 'agree', 'undecided', 'disagree', and 'strongly disagree' representing 5,4,3,2 and 1 scale respectively). Factors with mean score less than 3.0 were considered as those which experience less impact while those with mean score equal or above 3.0 were considered as high impacts of climate. The vulnerability index approach defined by Ranganathan et al (2009) was adopted and modified to assess the degree of vulnerability of the area: All the selected indicators were subjected to statistical analysis as followed:

- i. Normalization of indicators using functional relationship: Two types of functional relationship are possible: when the observed values are related positively to the vulnerability, the normalization was done by employing the formula below:

$$p_{ij} = \frac{x_{ij} - \min(x_{ij})}{\max(x_{ij}) - \min(x_{ij})} \dots \dots \dots$$

On another hand, when the values are negatively related to the vulnerability, the normalized score was computed using the formula below:

$$n_{ij} = \frac{x_{ij} - \min(x_{ij})}{\max(x_{ij}) - \min(x_{ij})} \dots \dots \dots$$

Where: Max = Maximum value of indicator

Min = Minimum value of indicators

X_{ij} = values of indicator j corresponding to Urban community i

P_{ij} = normalized score for observed values that are positively related to the vulnerability

N_{ij} = normalized score for observed values that are negatively related to the vulnerability

All the normalized scores for the two types of functional relationship were between 0 and 1. The value 1 corresponds to the urban community with highest vulnerability and 0 correspond to the Urban Community with lowest vulnerability.

i. Construction of vulnerability index: After computing the normalized scores, the index was constructed by giving equal weights to all indicators using single average of all the scores. The formula is given as:

$$VI = \frac{\sum P_{ij} + \sum N_{ij}}{K} \dots \dots \dots$$

Where: P_{ij} = normalized score for observed values that are positively related to the vulnerability

N_{ij} = normalized score for observed values that are negatively related to the vulnerability

K = indicators

VI = vulnerability index

Examining the degree of vulnerability: The degree of vulnerability of the community to climate change conditions was examined using vulnerability index categories: less vulnerable, moderately vulnerable, and highly vulnerable. The categories were modified from Ranganathan *et al* (2009) and are given against a scale of numerical value of vulnerability index as in Table 2

Table 1: Indicators and variables in computing Vulnerability indices

Determinants of Vulnerability	Component Indicators	Description of the Indicator	Unit of Measurement	Functional Relationship
Exposure	Changes in climate variables from selected base year	Change in Min. Temperature (1976-2016)	Degrees Celsius	+
		Change in Max. temperature (1976-2016)	Degrees Celsius	+
		Change in annual Rainfall (1976-2016)	Percentage change	+
	Extreme climate events	Frequency of Flood	Number of Floods hazards from 1976-2016	+
		Frequency of Droughts	Number of droughts hazards from 1976-2016	+
Sensitivity	Population Density	Total urban population per area	Population/Km ²	+
	Irrigated land	Percentage of irrigated land	Percentage	-
	Civil insecurity	Frequency of insecurity	Number of occurrences	+
	Occurrence of heat related diseases	Frequency of heat related diseases	Number of occurrences	+
	Urban infrastructure	Access to urban infrastructure	Average	+
Resilience and adaptive capacity	Housing	Well located Housing	percentage	—
	Literacy Rate	Proportion of persons who can read and write	Percentage	—
	Awareness and preparedness	Level of Preparedness for climate hazard	percentage	+
	Social Services: Providing food banks	level of urban population involved in food production	percentage	+
	Energy demand	Level of energy demand in community	percentage	-
	Technology such as green roofs	Level of urban population with green roofs and heat management strategy	Percentage	+
	Behavioural: rainwater harvesting	Percentage of population with access water	Percentage	+
	Ecosystem based: re-establishing wetlands	Level of ecosystem conservation in urban city	Percentage	+
	Health Care Services	Percentage of population with access within 4km	Percentage	-
	Economics such as insurance	level of insurance access	Naira	-

Source: modified from Ranganathan et al (2009)

Table 2: Modified Vulnerability Classification Values

Index Value	Stage of Vulnerability
0.00-0.40	Less Vulnerable
0.41-0.60	Moderately Vulnerable
0.61-1.00	Highly Vulnerable

Result of the Findings

Assessing Vulnerability of the Rural community to Climate Change

The result of the finding on assessing vulnerability of the rural community to Climate Change and how different climatic hazards impact the perceived vulnerability of rural households across various ecological zones within Taraba State is presented in Table 4.

Table 4. Assessing Vulnerability of the Rural community to Climate Change

	Sudan Savannah	Northern Guinea Savannah	Southern Guinea Savannah	Montane	Mean	Rank
Flood	3.5242	2.9968	2.2491	2.3732	2.7858	1 st
Rural Heat	2.0409	3.1780	2.6797	2.8373	2.6840	2 nd
Windstorms	1.5799	3.1230	3.0036	3.0191	2.6814	3 rd
Drought	3.0446	2.7379	1.7438	1.8900	2.3540	4 th
Mean	2.5474	3.0089	2.4190	2.5299		
Rank	2nd	1st	4th	3rd		

Table 4 quantifies the level of vulnerability to specific climate change impacts: Flood, Rural Heat, Windstorms, and Drought. Overall, Flooding emerges as the primary climate change impact to which rural communities in Taraba State feel most vulnerable, ranking 1st with a mean score of 2.7858. This suggests that floods are a significant concern across the region, posing the highest perceived threat to livelihoods and well-being.

"Rural Heat" and "Windstorms" follow closely, ranking 2nd and 3rd respectively, with mean scores of 2.6840 and 2.6814. The similar scores indicate that both heat and wind-related events are significant, though slightly less impactful than flooding. Drought is perceived as the least significant vulnerability, ranking 4th with a mean of 2.3540, suggesting its impact is less widespread or severe compared to the other hazards in the perception of the surveyed households.

Analyzing the vulnerability across the ecological zones, the Northern Guinea Savannah exhibits the highest overall mean vulnerability score (3.0089), ranking 1st. This implies that communities in this zone perceive themselves as most vulnerable to the combined effects of the listed climate hazards. This zone shows relatively high scores across all hazards, particularly for rural heat and windstorms.

Conversely, the Southern Guinea Savannah ranks 4th in overall vulnerability (mean 2.4190), indicating a comparatively lower perceived vulnerability to these specific climate change impacts. Within this zone, vulnerability to drought and flood appears to be particularly low.

The Sudan Savannah ranks 2nd overall (mean 2.5474), with a notably high perceived vulnerability to flood and drought. The Montane zone ranks 3rd (mean 2.5299), showing relatively higher vulnerability to windstorms and rural heat compared to flood and drought.

These findings are critical for targeted climate change adaptation and disaster risk reduction strategies. They highlight that while flooding is a pervasive concern, the specific climate change

impacts causing vulnerability vary across different ecological zones, necessitating tailored interventions that address the unique vulnerabilities of each region.

Table 5. Vulnerability index of the selected Agro-ecological Zones

	Parameters	Montane	Southern Savannah	Northern Savannah	Sudan
Exposure	Change in annual rainfall	0.46	0.53	0.46	0.5
	Change in Max. Temp	0.57	0.43	0.45	0.46
	Change in Min. Temp	0.52	0.55	0.59	0.43
	Frequency of flood	0.47	0.43	0.33	0.29
	Frequency of Drought	0.55	0.5	0.35	0.26
Sensitivity	Irrigation level	0.86	0.85	0.86	0.76
	Occurrence of heat	0.46	0.42	0.54	0.26
	Civil insecurity	0.43	0.32	0.42	0.4
	Housing	0.51	0.59	0.75	0.72
	Technology such as green roof.	0.65	0.60	0.75	0.60
Resilience and adaptation	Ecosystem based re-establishing wetland.	0.58	0.58	0.74	0.73
	Economics such as insurance.	0.43	0.47	0.69	0.75
	Awareness preparedness	0.59	0.49	0.73	0.8
	Social sense: food bank	0.85	0.88	0.78	0.69
	Rainwater harvesting	0.60	0.64	0.76	0.57
	Energy demand	0.49	0.48	0.73	0.75
	Healthcare services	0.56	0.53	0.65	0.61
	Literacy	0.12	0.15	0.38	0.40
Index		0.54	0.52	0.61	0.55
Rank		3 rd	4 th	1 st	2 nd

Note: 0.00-0.40 is Less Vulnerable, 0.41-0.60 is Moderately Vulnerable and 0.61-1.00 is Highly Vulnerable

Table 5 presents the vulnerability index of four selected agro-ecological zones Montane, Southern Savannah, Northern Savannah, and Sudan based on three broad parameters: Exposure, Sensitivity, and Resilience/Adaptation.

Exposure: This measures the degree to which these zones experience climate-related stressors like changes in rainfall, maximum and minimum temperature variations, and the frequency of floods and droughts. For example, Southern Savannah shows the highest vulnerability for changes in annual rainfall (0.53) and minimum temperature (0.55), while Montane and Northern Savannah show moderate values. Frequency of drought is highest in the Montane (0.55) and Southern Savannah (0.5) zones.

Sensitivity: This captures how susceptible the zones are to these stresses based on factors like irrigation levels, heat occurrence, and civil insecurity. All zones show high irrigation sensitivity (around 0.76 to 0.86), indicating that irrigation practices are critical and vulnerable components. Heat occurrence varies, with Northern Savannah most sensitive (0.54). Civil insecurity is relatively moderate across all zones.

Resilience and Adaptation: This reflects the capacity of the zones to cope with and adapt to climate impacts, including housing quality, technological interventions (e.g., green roofs), ecosystem restoration, economic tools like insurance, awareness and preparedness, social supports

such as food banks, rainwater harvesting, energy demand, healthcare, and literacy. Here, Northern Savannah generally shows higher scores (e.g., housing 0.75, green roof 0.75, awareness 0.73), indicating better adaptive capacity, while Southern Savannah and Sudan have mixed scores.

Overall Vulnerability Index: Combining these factors, the Northern Savannah is the most vulnerable (0.61), classified as highly vulnerable, followed by Sudan (0.55) and Montane (0.54), both moderately vulnerable. Southern Savannah is the least vulnerable (0.52), but still moderately vulnerable.

Ranking: Northern Savannah ranks 1st in vulnerability (most vulnerable), Sudan 2nd, Montane 3rd, and Southern Savannah 4th (least vulnerable).

Interpretation: Zones with higher exposure and sensitivity and lower resilience/adaptation scores are more vulnerable to climate change impacts. Northern Savannah's high vulnerability suggests urgent need for targeted interventions to reduce risk, improve adaptation measures, and strengthen resilience. Other zones also require attention but may have relatively better adaptive capacity or lower exposure.

Discussion of Results

The study revealed significant climate-induced vulnerabilities across the agroecological zones of Taraba State, with marked spatial variability in exposure, sensitivity, and adaptive capacity. These findings align with existing literature that emphasizes the spatial heterogeneity of climate risks and the need for localized adaptation strategies (Ford et al., 2022; Hahn et al., 2009).

Flooding emerged as the most significant hazard affecting rural livelihoods, especially in the Sudan Savannah and Northern Guinea Savannah zones. This is consistent with findings by Nkwunonwo, Whitworth and Baily (2021), who documented that flooding is increasingly becoming the most destructive climate hazard in Nigeria, exacerbated by deforestation, poor drainage, and unplanned settlements. Similarly, the high vulnerability to flooding reported in this study echoes the IPCC's (2022) recognition of extreme weather events as major stressors in sub-Saharan Africa.

The high vulnerability to rural heat and windstorms, particularly in the Northern Guinea Savannah and Montane zones, supports earlier studies which have indicated that increased temperature extremes and erratic wind patterns pose serious risks to subsistence farming and rural infrastructure (Gebrechorkos et al., 2020; Palazzi et al., 2021). The impacts of heat stress, particularly in terms of crop yield decline and livestock mortality, have been extensively documented in other African regions (Mekonnen et al., 2022).

Interestingly, drought was perceived as the least impactful hazard, a finding that contrasts with broader national narratives where drought is typically cited as a critical climate risk (Adefolalu, 2007). This discrepancy may reflect short-term perceptions influenced by recent flood events or differences in adaptive knowledge related to water conservation. However, the vulnerability index suggests otherwise, especially in Montane and Southern Savannah zones, where drought frequency scores were relatively high. This misalignment between perception and empirical exposure highlights the need for improved climate literacy and community-level education (Ayanlade, Radeny & Morton, 2020).

The Northern Savannah zone was identified as the most vulnerable, with a composite index of 0.61, categorizing it as highly vulnerable. This supports the assertion by Eze, Olatunji, and Asogwa (2019) that climate impacts in Nigeria are exacerbated by social inequalities and lack of

infrastructural support in rural regions. Moreover, the zone exhibited relatively high exposure and sensitivity, alongside moderate resilience, which is insufficient to offset climate risks. This finding is consistent with the work of Tariq, Zhang, and Khan (2023), who stressed that even in the presence of moderate adaptive measures, high exposure and sensitivity could overwhelm community resilience.

Adaptive capacity across the zones remains weak, as shown by low scores in literacy, insurance access, and healthcare availability. This mirrors the observations of the UNEP (2023) Adaptation Gap Report, which emphasized that underfinanced and underprepared rural communities are at the forefront of climate vulnerability. The observed limited uptake of ecosystem-based adaptation practices, such as re-establishing wetlands or green roofing, also aligns with findings by Ali *et al* (2021), who reported that despite their proven efficacy, these strategies remain underutilized in mountain communities due to financial and knowledge barriers.

Furthermore, the study affirmed the role of socioeconomic and infrastructural deficits such as limited irrigation, food insecurity, and inadequate housing in shaping vulnerability, in line with the livelihood vulnerability framework proposed by Hahn *et al* (2009) and the sustainable livelihoods approach advocated by Scoones (2015). These structural weaknesses, compounded by exposure to extreme weather, undermine not only productivity but also the social fabric of communities through forced migration, intergroup conflict, and deepening inequality (Fagbemi & Olorunfemi, 2019).

Notably, the Montane zone, despite being ecologically distinct and often perceived as more resilient due to cooler climates, also displayed moderate vulnerability (index = 0.54). This confirms findings by Körner, Paulsen, and Spehn (2017), who noted that mountain regions are not immune to climate change; in fact, their fragility is often masked by temporary climatic advantages. The frequent landslides and erosion noted in the Mambilla Plateau reflect similar trends observed in global mountainous regions (Pepin *et al.*, 2022).

Overall, the study underscores that climate vulnerability in Taraba State is a multidimensional and place-based phenomenon, influenced by the interaction of environmental, socioeconomic, and institutional factors. These findings support the call for context-specific, community-led adaptation planning and the integration of local knowledge into national climate strategies (Adger, 2006; IPCC, 2022).

Conclusion

This study assesses climate vulnerability across the agroecological zones of Taraba State, revealing significant spatial differences in exposure, sensitivity, and adaptive capacity. The Northern Savannah zone emerged as the most vulnerable, primarily due to high exposure to heat and windstorms, weak infrastructure, and limited adaptive resources. In contrast, the Southern Savannah exhibited the lowest overall vulnerability but still faced moderate risks, especially from flooding. Flooding was identified as the most significant climate hazard across all zones, posing serious threats to agriculture, housing, and livelihoods. The study also highlighted the role of socioeconomic factors such as poor access to education, healthcare, and insurance in exacerbating vulnerability, particularly in the more isolated rural areas. The findings demonstrate that climate vulnerability in Taraba State is not uniform and must be addressed through locally tailored strategies. Enhancing adaptive capacity by improving infrastructure, promoting education, supporting local knowledge, and integrating community-led initiatives is essential for building resilience. This study contributes to a more nuanced understanding of climate risks in rural Nigeria

and offers a valuable evidence base for targeted policy interventions and sustainable development planning.

Recommendations

Based on the findings, the following recommendations were made;

- i. **Implement Zone-Specific Climate Adaptation Strategies:** Since vulnerability varies across agroecological zones, interventions should be tailored to local conditions. For instance, flood control measures are critical in the Sudan and Northern Guinea Savannah zones, while drought resilience strategies should be prioritized in the Montane areas.
- ii. **Strengthen Rural Infrastructure and Social Services:** Investment in basic infrastructure such as roads, irrigation, healthcare, and education can reduce sensitivity and improve adaptive capacity. Improved access to health and education services also empowers communities to respond better to climate threats.
- iii. **Promote Climate-Resilient Agriculture:** Encourage the adoption of drought-tolerant crops, sustainable land use, and improved irrigation systems. This would help mitigate yield losses from irregular rainfall, heatwaves, and soil erosion, especially in high-risk zones.
- iv. **Enhance Access to Climate Information and Early Warning Systems:** Provide timely, localized climate forecasts through extension services and local radio to help farmers make informed decisions. This is especially needed in zones with high exposure but low awareness.
- v. **Support Ecosystem-Based Adaptation Practices:** Restore wetlands, promote agroforestry, and protect water catchment areas to enhance natural resilience. These practices are underutilized but essential in flood- and erosion-prone areas.
- vi. **Promote Insurance and Financial Inclusion:** Facilitate access to agricultural insurance, credit, and savings schemes to help households recover from climate shocks. Financial tools can buffer the impacts of crop failure or disaster-related losses.
- vii. **Empower Vulnerable Groups (Women and Youth):** Target support toward women and youth who face disproportionate vulnerability due to limited asset ownership and decision-making power. Programs should focus on skills training, education, and inclusive governance.

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