Climate Change Vulnerability and Adaptation Strategies in Artisanal and Small-scale Mining Communities in the Central Zone of Taraba State, Nigeria

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Article Info

ISSN (online): 2582-7138
Volume: 06
Issue: 04
July - August 2025
Received: 21-05-2025
Accepted: 24-06-2025
Published: 06-07-2025
Page No: 567-571

Abstract
The study was conducted in the Central Zone of Taraba State, located in northeastern Nigeria, between latitudes 6°30'N and 8°30'N and longitudes 10°00'E and 11°30'E. This region includes key Local Government Areas (LGAs) such as Bali, Gashaka, and Sardauna, where artisanal and small-scale mining (ASM) activities are extensively practiced. Ecologically, the zone spans two major eco-regions: the Guinea Savanna lowlands and the montane grasslands of the Mambilla Plateau, the latter rising to altitudes above 1,500 meters above sea level. The climate is tropical sub-humid, characterized by a distinct rainy season from April to October and a dry season from November to March, driven by the seasonal oscillation of the Intertropical Convergence Zone (ITCZ). Mean annual rainfall varies across elevation gradients, ranging from 1,200 mm in Bali to over 2,500 mm in Sardauna, with pronounced intra-annual and inter-annual variability.

DOI: https://doi.org/10.54660/.IJMRGE.2025.6.4.567-571

Keywords: Climate change, Artisanal mining, Vulnerability, Adaptation, Taraba State, Nigeria, Livelihoods, Environmental policy

1. Introduction

Climate change constitutes an existential global challenge with deeply asymmetric impacts across regions, sectors, and socioeconomic groups. While no community remains unaffected, the consequences are disproportionately borne by resource-dependent populations engaged in informal livelihoods, particularly those with limited institutional support and adaptive capacity (IPCC, 2022). Among such vulnerable groups, artisanal and small-scale mining (ASM) communities are increasingly recognized as being at the frontline of climate-related risks (Hilson & Van Bockstael, 2018; Nwankwo *et al*., 2021) [3, 7].

Artisanal and small-scale mining, often operating outside formal regulatory regimes, contributes significantly to rural employment and income generation in sub-Saharan Africa. In Nigeria, the sector engages over 500,000 people either directly or indirectly, with operations spread across mineral- rich but infrastructure-poor regions (Ministry of Mines and Steel Development, 2021). The Central Zone of Taraba State—encompassing Local Government Areas such as Bali, Gassol, Gashaka, Kurmi, and Sardauna—is one such region. Here, ASM is focused on the extraction of gold, barite, lead, zinc, and gemstones, often in ecologically sensitive landscapes including the Mambilla Plateau and areas adjoining the Gashaka-Gumti National Park.

Environmental degradation associated with ASM including deforestation, soil erosion, water pollution, and biodiversity loss—has been well documented (Aliyu *et al*., 2017; Ajibade & Adegoke, 2019) [1, 2]. However, what remains under-explored in both academic literature and policy discourse is the interaction between ASM and climate change. ASM communities in Taraba are increasingly affected by climatic stressors, such as erratic rainfall patterns, seasonal water scarcity, and temperature extremes, which disrupt mining activities, undermine health and safety, and threaten food and water security. The sector's informal character, coupled with weak institutional frameworks and poor access to early warning systems, significantly limits proactive adaptation.

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Although Nigeria has adopted a National Adaptation Strategy and Plan of Action on Climate Change (NASPA-CCN), as well as state-level adaptation frameworks, these instruments rarely integrate ASM as a sector of concern. Consequently, climate adaptation in ASM zones remains autonomous, reactive, and largely unsupported by formal governance mechanisms. This governance gap exacerbates exposure and reinforces cycles of vulnerability, particularly for marginalized groups such as women and youth who form a significant portion of the ASM labor force.

Globally, there is a growing call to reframe climate adaptation through the lens of informal economies and livelihood pluralism, recognizing that adaptation must be grounded in local realities and knowledge systems (Yaro *et al*., 2015; IPCC, 2022) [9]. Yet empirical studies that document how ASM communities experience, perceive, and respond to climate change, particularly in West Africa, remain limited. Understanding the specific dynamics of vulnerability and adaptation within ASM settings is therefore critical to informing inclusive and context-sensitive climate policy.

This study addresses this knowledge gap by investigating climate vulnerability and adaptation strategies among ASM communities in the Central Zone of Taraba State, Nigeria. It applies the Intergovernmental Panel on Climate Change (IPCC)'s vulnerability assessment framework, which conceptualizes vulnerability as a function of exposure to climate hazards, sensitivity to impacts, and the capacity to adapt. Through a mixed-methods approach, comprising household surveys, key informant interviews, and geo-spatial analysis, this study seeks to Identify and characterize the major climate-related stressors impacting ASM communities, assess local perceptions of climate change and its effects on mining and livelihoods, analyse existing adaptive responses and their effectiveness and explore the institutional and infrastructural barriers to climate resilience.

2. Method

2.1. Study Area

The study was conducted in the Central Zone of Taraba State, located in northeastern Nigeria, between latitudes 6°30'N and 8°30'N and longitudes 10°00'E and 11°30'E. This region includes key Local Government Areas (LGAs) such as Bali, Gashaka, and Sardauna, where artisanal and small-scale mining (ASM) activities are extensively practiced. Ecologically, the zone spans two major eco-regions: the Guinea Savanna lowlands and the montane grasslands of the Mambilla Plateau, the latter rising to altitudes above 1,500 meters above sea level. The climate is tropical sub-humid, characterized by a distinct rainy season from April to October and a dry season from November to March, driven by the seasonal oscillation of the Intertropical Convergence Zone (ITCZ). Mean annual rainfall varies across elevation gradients, ranging from 1,200 mm in Bali to over 2,500 mm in Sardauna, with pronounced intra-annual and inter-annual variability.

Study Locations in the Central Regions

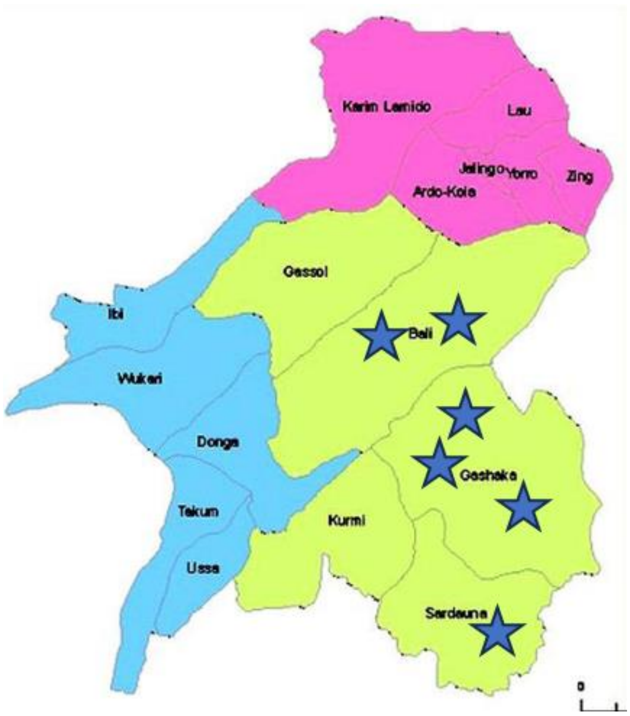

Fig 1: Map of the Study Area (Taraba State Government)

2.2 Research Design

A mixed-method approach was employed to combine quantitative and qualitative data for a comprehensive vulnerability assessment.

2.3 Data Collection

Household Surveys (n=250) across five major ASM communities (Mayo-Sinna, Gidan Kara, Maijankasa, Lambangudu, and Quenty Gate). Focus Group Discussions (FGDs) with miners, women, and youth groups. Key Informant Interviews (KIIs) with local leaders, mining officers, and environmental health workers.

2.4 Analytical Framework

The vulnerability assessment followed the IPCC's model:

Exposure: Degree to which ASM communities experience climatic hazards (e.g., rainfall variability, flooding, heatwaves).

Sensitivity: Degree to which ASM livelihood systems are affected.

Adaptive Capacity: Ability to adjust, cope, or recover from climate impacts.

Data were analyzed using descriptive statistics, thematic content analysis, and a climate vulnerability index (CVI) derived from weighted indicators.

3. Results

Table 1: Household Survey Summary (n = 250)

This table presents responses from 250 households across five artisanal mining communities regarding climate variability and adaptation.

Increased Rainfall Variability: Over 70% of respondents in each community perceive changes in rainfall, with Lambangudu reporting the highest (88%) and Quenty Gate the lowest (70%).

Prolonged Dry Season: Most respondents across all locations notice longer dry seasons, peaking in Lambangudu (94%) and lowest in Quenty Gate (76%).

Reduced Mining Season: Indicates seasonal limitation in mining due to weather. Lambangudu (70%) and Mayo-Sinna (66%) report high levels.

Water Scarcity for Processing Reported heavily in Lambangudu (78%) and Mayo-Sinna (74%), suggesting serious water access issues.

Mining Accidents During Floods: More common in Lambangudu (40%) and Maijankasa (36%), indicating exposure to hazards during the rainy season.

Water Storage Practices: The use of tanks or dugouts is highest in Lambangudu (50%) and lowest in Maijankasa (30%).

Livelihood Diversification: A majority engage in other income activities, especially in Lambangudu (72%) and Maijankasa (66%).

Saving Group Membership: Highest in Lambangudu (80%) and lowest in Maijankasa (58%), showing community solidarity variation.

Access to Early Warning Systems: Extremely low across all communities, with Quenty Gate at 0%, suggesting poor dissemination of climate risk information.

No Formal Adaptation Training: Alarmingly high across all locations, with Quenty Gate (98%) and Gidan Kara (96%) showing the greatest lack (Table 1).

Table 2: Focus Group Discussion (FGD) Themes

This table summarizes insights from community discussions.

Climate Knowledge: Predominantly gained through personal experience, with no formal instruction.

Risk Perception: High concern due to observable changes like reduced stream flow, increased heat, and unpredictable rainfall.

Adaptive Practices: Include shifting mining seasons, relying on surface water, seasonal migration, and engaging in dry-season agriculture.

Barriers: Include lack of credit, absence of government support, and poor access to reliable information.

Coping Mechanisms: Rely on traditional systems, labor-sharing, community savings (esusu), and water pit re-digging (Table 2).

Table 3: Key Informant Interview Excerpts (n = 15)

This table features statements from leaders and officials.

Government Mining Officer: Admits absence of structured climate response, indicating institutional weakness.

Youth Leader: Emphasizes reduced mining seasonality, confirming survey trends.

Traditional Ruler: Highlights local tree-planting efforts and the lack of external aid.

Women's Leader: Describes hardship of water storage using plastic tanks, often fetched from far distances (Table 3).

Table 4: Climate Vulnerability Index (CVI)

This table shows calculated vulnerability scores using three indicators: exposure, sensitivity, and adaptive capacity.

Mayo-Sinna: Highest vulnerability (0.68) due to high exposure (0.78) and low adaptive capacity (0.45).

Lambangudu: High exposure and sensitivity but relatively better adaptive capacity (0.60), resulting in a moderate CVI (0.66).

Quenty Gate: Lowest CVI (0.61) but also the least adaptive (0.35), suggesting less perceived pressure rather than resilience.

Maijankasa and Gidan Kara: Moderate vulnerability, but all communities are above 0.60, signaling general high climate vulnerability (Table 4).

Table 5: Recorded Environmental Impacts by Site (2024)

This table documents field observations of environmental changes.

Dry Stream Beds: Universally observed, confirming severe water stress.

Flooded Pits: Highest in Maijankasa and Lambangudu; suggests risk of water-related accidents and disruption.

Dust Levels: Very high in Lambangudu; others report high to moderate, indicating severe air quality degradation.

Vegetation Loss: Severe in Mayo-Sinna and Lambangudu, supporting evidence of deforestation from mining activities.

Perceived Temperature Rise: Universally noted, with Mayo-Sinna and Lambangudu again rating "very high" (Table 5).

Table 1: Household Survey Summary (n = 250)

Variable	Mayo-Sinna (n=50)	Gidan Kara (n=50)	Maijankasa (n=50)	Lambangudu (n=50)	Quenty Gate (n=50)
% reporting increased rainfall variability	84%	80%	76%	88%	70%
% reporting prolonged dry season	90%	85%	78%	94%	76%
% reporting reduced mining season	66%	58%	64%	70%	52%
% observing water scarcity for processing	74%	69%	65%	78%	60%
% reporting mining accidents during floods	28%	22%	36%	40%	30%
% using water tanks or dugouts for storage	38%	42%	30%	50%	32%
% practicing livelihood diversification	60%	54%	66%	72%	50%
% belonging to local saving groups	72%	65%	58%	80%	60%
% with access to early warning systems	6%	2%	4%	10%	0%
% with no formal adaptation training	92%	96%	88%	84%	98%

Table 2: Focus Group Discussion Results (Key Themes Identified)

Theme	Summary from FGDs
Climate change knowledge	Mostly experiential; no formal education on climate issues
Risk perception	High concern about rainfall changes, heat stress, and drying of local streams
Common adaptive practices	Shifting mining to the early rainy season, using surface water storage, seasonal migration, and starting dry-season farming
Barriers to adaptation	Lack of credit, poor access to information, and absence of support from government agencies
Community coping mechanisms	Informal labor-sharing groups, esusu savings, collective re-digging of water pits

Table 3: Key Informant Interview Excerpts (n = 15)

Respondent	Role	Notable Statement
Mining Officer, Sardauna LGA	Gov't official	"We have no structured climate response for artisanal miners. Most rely on intuition."
Youth leader, Maijankasa	Community rep	"Our streams dry earlier every year. We now mine mostly between April and June."
Traditional ruler, Lambangudu	Local leader	"Our people replant trees, but few outsiders support us."
Women's group leader	Cooperative rep	"We use plastic tanks to fetch and store water from distant wells."

Table 4: Climate Vulnerability Index (CVI) Scores per Community

Community	Exposure	Sensitivity	Adaptive Capacity	CVI Score
Mayo-Sinna	0.78	0.72	0.45	0.68
Gidan Kara	0.74	0.68	0.40	0.64
Maijankasa	0.70	0.70	0.52	0.64
Lambangudu	0.82	0.75	0.60	0.66
Quenty Gate	0.66	0.60	0.35	0.61

Based on weighted indicators (exposure, sensitivity, adaptive capacity), scale 0–1 (1 = highest vulnerability)

Table 5: Recorded Environmental Impacts by Site (2024 Observations)

Environmental Indicator	Mayo-Sinna	Gidan Kara	Maijankasa	Lambangudu	Quenty Gate
Dry stream beds (April–May)	Yes	Yes	Yes	Yes	Yes
Flooded pits during rains	Moderate	Low	High	High	Moderate
Dust levels (dry season)	High	High	High	Very High	Moderate
Vegetation loss	Severe	Moderate	Moderate	Severe	Moderate
Temperature rise perception	Very High	High	Moderate	Very High	High

4. Discussion

This study reveals that artisanal and small-scale mining (ASM) communities in the Central Zone of Taraba State are significantly vulnerable to climate change impacts, which compound the existing environmental degradation from informal mining practices. The concept of "double exposure"where communities face simultaneous environmental and climatic threats, is clearly evident. Climate-related changes such as erratic rainfall, increasing surface temperatures, and seasonal water scarcity have intensified the already precarious conditions under which ASM operates.

This pattern of dual vulnerability is not confined to Taraba. In Zamfara State, Aliyu *et al.* (2017) [2] documented how ASM communities face recurrent health and environmental crises due to heavy metal contamination, further worsened by seasonal floods that spread mining waste into surrounding farmlands. Similarly, in Niger State, research by Ibrahim *et al*. (2020) observed that extreme rainfall variability has led to periodic flooding of mine shafts and pits, disrupting mining operations and heightening accident risks. These studies, like our findings in Taraba, highlight the intersection of unregulated ASM and worsening climatic variability.

In Osun and Ondo States, Ajibade *et al*. (2019) [1] found that ASM communities were already struggling with land degradation and water shortages, but climate-induced changes, especially prolonged dry spells, have reduced water availability for ore processing and increased inter-community conflict over stream access. In our study, comparable trends were reported, with over 70% of miners in Lambangudu and Mayo-Sinna reporting seasonal stream bed drying and disrupted mining calendars. The similarities in these findings across agroecological zones suggest a nationwide pattern of ASM vulnerability to climate variability, particularly around water resources.

What distinguishes the Taraba context, however, is its complex topography (e.g., Mambilla Plateau), relative isolation, and transhumance pressure, which intensify both environmental sensitivity and limits to adaptive capacity. Our data show that although local miners adopt informal adaptations, like changing mining calendars, using plastic tanks for water storage, or diversifying into seasonal farming, these responses are mostly autonomous, short-term, and reactive. This aligns with the findings of Nwankwo *et al.* (2021) [7] in Plateau State, where miners developed adaptive behaviors in response to changing rainfall and temperature but lacked institutional support or access to climate-resilient technologies.

Moreover, a consistent theme across studies from other Nigerian ASM regions is the absence of integration between climate policy and mining governance. Despite Nigeria's National Adaptation Strategy and various State Action Plans on Climate Change (SAPCC), the ASM sector remains marginalized in climate planning. In Taraba, this gap is further exacerbated by weak local institutions, limited technical support, and inadequate data on ASM–climate linkages.

The adaptations observed in Taraba are commendable for their resourcefulness, but they are insufficient for long-term resilience. In several communities, the digging of informal water reservoirs, replanting of shade trees, and cooperative-based savings groups represent important coping mechanisms. However, without institutional reinforcement, such as microcredit access, early warning systems, climate-resilient infrastructure, and technical extension services, these adaptations may become maladaptive, locking communities into vulnerable practices.

Comparatively, Osun and Niger States have piloted some formal interventions, such as environmental remediation programs (funded by government and donor agencies), which could serve as models for adaptation support in Taraba. These initiatives, however, remain limited in scope and have not been institutionalized at the national scale.

5. Policy Recommendations

1. Incorporate ASM into Nationally Determined Contributions (NDCs) and State Action Plans on Climate Change.
2. Support climate-smart mining practices, including low-water processing and reforestation of mined lands.
3. Enhance financial inclusion and access to microcredit for miners to diversify livelihoods.
4. Strengthen local institutions (e.g., miners' cooperatives) as vehicles for climate education and risk pooling.
5. Establish early warning systems and integrate climate data into local planning.
6. Promote land use planning that protects watersheds and reduces environmental sensitivity.

6. Conclusion

In conclusion, climate resilience in ASM communities cannot be achieved through informal coping strategies alone. It requires coordinated, context-sensitive approaches that address both the environmental and socioeconomic dimensions of vulnerability. Advancing such resilience is not only vital for the sustainability of rural livelihoods but is also a strategic pathway toward equitable, climate-informed development planning in Nigeria’s resource-dependent regions.

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