

Geological Hazards and Risk Assessment in Nigeria – A Review

U.A. Usman¹; N. A. Yelwa²; M.M. Aji¹; A. I. Mohammed³, S.N. Giwa⁴

¹Department of Geology, Faculty of Physical Sciences, University of Maiduguri, Borno State, Nigeria.

²Geology Department, Faculty of Physical and Computing Sciences, Usman Danfodiyo University, Sokoto State, Nigeria.

³Department of Pure and Applied Chemistry, Faculty of Physical Sciences, University of Maiduguri, Borno State, Nigeria

⁴Department of Geological Technology, Federal Polytechnic Offa, Kwara State Nigeria

*Corresponding author's email: uausman@unimaid.edu.ng

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ABSTRACT

Nigeria faces significant challenges from geological hazards, including landslides, gully erosion, flooding, coastal erosion, drought, desertification, and minor seismic tremors. These hazards are driven by a combination of natural factors, such as geological structures, climatic conditions, and human activities, including deforestation, urbanization, and poor land-use practices. The impacts of these hazards are far-reaching, affecting economic development, social stability, and environmental sustainability. This review highlights the need for a comprehensive national geological hazard risk assessment and mitigation framework that incorporates both structural and non-structural measures. Effective mitigation strategies require a combination of engineering solutions, policy instruments, land-use planning, institutional strengthening, and public awareness. Recent advances in geospatial technologies, remote sensing, and geographic information systems (GIS) offer opportunities to improve hazard monitoring and assessment. However, addressing the challenges of data limitations, infrastructure constraints, and institutional fragmentation will be crucial to reducing the risks associated with geological hazards in Nigeria. This study emphasizes the importance of integrating geological hazard mitigation into national development planning, disaster risk reduction, and sustainable development initiatives.

Keywords: Geohazards. Risk Assessment. Disaster Management. Vulnerability Analysis. Nigeria.

1.0 INTRODUCTION

Geological hazards constitute a major component of natural hazards that pose significant threats to human lives, infrastructure, ecosystems, and socio-economic development globally. In developing countries, particularly those with rapidly growing populations and weak land-use control systems, the impacts of geological hazards are often amplified due to high vulnerability and limited adaptive capacity. Nigeria, Africa's most populous nation, has increasingly experienced diverse geological hazards such as landslides, gully erosion, flooding, coastal erosion, drought, desertification, and minor seismic tremors, resulting in substantial environmental degradation and economic losses (Adelekan, 2020; Ologunorisa & Adeyemo, 2019). Despite the growing frequency and severity of these events, comprehensive national-scale geological hazard risk assessment and mitigation frameworks remain fragmented.

1.1 Definition of Geological Hazards and Risk Assessment

Geological hazards refer to naturally occurring geological or geomorphological processes that have the potential to cause harm to humans, damage infrastructure, and disrupt socio-economic activities. These hazards arise from the dynamic interactions between the Earth's lithosphere, hydrosphere, atmosphere, and biosphere, and include phenomena such as landslides, erosion, earthquakes, volcanic activity, subsidence, and coastal instability (Fell *et al.*, 2020; Gill and Malamud, 2014). In the Nigerian

context, geological hazards are largely surface and near-surface processes driven by climatic variability, weathering, tectonic structures, and human interference with the natural environment (Abbas *et al.*, 2021; Egbueri *et al.*, 2025).

Risk assessment, on the other hand, is a systematic process that evaluates the likelihood of hazard occurrence and the magnitude of its potential consequences. According to UNDRR (2019), risk is a function of hazard, exposure, and vulnerability, expressed as:

$$\text{Risk} = \text{Hazard} \times \text{Exposure} \times \text{Vulnerability}$$

Geological risk assessment therefore involves hazard identification, spatial analysis of hazard probability, evaluation of exposed elements (population, infrastructure, economic assets), and assessment of vulnerability and resilience. Recent advances in geospatial technologies, remote sensing, and geographic information systems (GIS) have significantly enhanced geological hazard risk assessment by enabling spatially explicit mapping, scenario modeling, and decision support (Akinyemi *et al.*, 2022; Kumari *et al.*, 2025).

In Nigeria, geological risk assessment has traditionally been reactive, focusing on post-disaster response rather than proactive risk reduction. However, recent studies emphasize the need for integrated, multi-hazard risk assessment frameworks that incorporate both natural

and anthropogenic drivers of geological hazards (Ishola *et al.*, 2021; Ejemeyovwi *et al.*, 2022).

1.2 Importance of Geological Hazard Mitigation in Nigeria

The importance of geological hazard mitigation in Nigeria cannot be overstated, given the country's rapid urbanization, population growth, climate variability, and increasing pressure on land and natural resources. Geological hazards have resulted in repeated loss of lives, displacement of communities, destruction of transportation networks, agricultural lands, and public infrastructure, with significant implications for national development (Berger, 2006; Nkwunonwo *et al.*, 2020).

Flooding and gully erosion alone account for billions of naira in annual economic losses, particularly in southeastern and southwestern Nigeria (Egbinola *et al.*, 2021; Nwokocha, 2021). Landslides in parts of southeastern Nigeria and the Mambilla Plateau have caused fatalities and rendered farmlands unusable, while coastal erosion threatens major economic hubs such as Lagos, Brass, and Forcados (Adelekan *et al.*, 2019; Iwuchukwu *et al.*, 2023). Drought and desertification in northern Nigeria exacerbate food insecurity, rural poverty, and resource-based conflicts, thereby intensifying national security challenges (Mortimore, 2020; Kerry, 2024).

Mitigation of geological hazards is therefore critical for achieving Nigeria's sustainable development goals (SDGs), particularly those related to poverty reduction, food security, climate action, and resilient infrastructure. Effective mitigation strategies reduce vulnerability, enhance adaptive capacity, and minimize long-term economic losses. Contemporary studies emphasize the integration of geological hazard mitigation into land-use planning, environmental impact assessment, disaster risk governance, and climate adaptation strategies (Azadi *et al.*, 2020; Oladipo *et al.*, 2022).

1.3 Overview of Nigeria's Geological Setting and Hazard Profile

Nigeria's geological and tectonic framework plays a fundamental role in shaping the spatial distribution and characteristics of geological hazards across the country. The geology of Nigeria (Fig. 1) is broadly divided into the Precambrian Basement Complex, Jurassic Younger Granites, and sedimentary basins of varying ages (Obaje, 2019; Tijani, 2023). These geological units influence soil development, slope stability, drainage patterns, and susceptibility to erosion and mass movement.

The Basement Complex, which underlies approximately 60% of Nigeria, is characterized by fractured crystalline rocks that are prone to intense weathering, slope instability, and gully erosion,

particularly in southeastern and north-central Nigeria (Anifowose *et al.*, 2021). Sedimentary basins such as the Niger Delta, Benue Trough, Chad Basin, and Dahomey Basin are associated with flooding, subsidence, coastal erosion, and shoreline retreat due to unconsolidated sediments and high groundwater levels (Wright, 1985; Nwankwoala & Warmate, 2020).

Climatically, Nigeria spans humid tropical conditions in the south to semi-arid and arid environments in the north. This climatic gradient significantly influences hazard types and intensities. High rainfall intensities in southern Nigeria trigger flooding, landslides, and erosion, while prolonged dry seasons in the north promote desertification and drought (Adefisan *et al.*, 2020; Unigwe, 2023). Climate change has further intensified extreme weather events, increasing the frequency and magnitude of hydro-geological hazards nationwide (Jiang, and tan, 2021; IPCC, 2021).

Although Nigeria is considered a tectonically stable region, recent studies have documented minor seismic tremors linked to reactivated faults within the Basement Complex and the Benue Trough, raising concerns about seismic risk in areas previously considered aseismic (Adewole and Healy, 2017; Olatunji *et al.*, 2021). These findings underscore the need for continuous monitoring and updated hazard assessments.

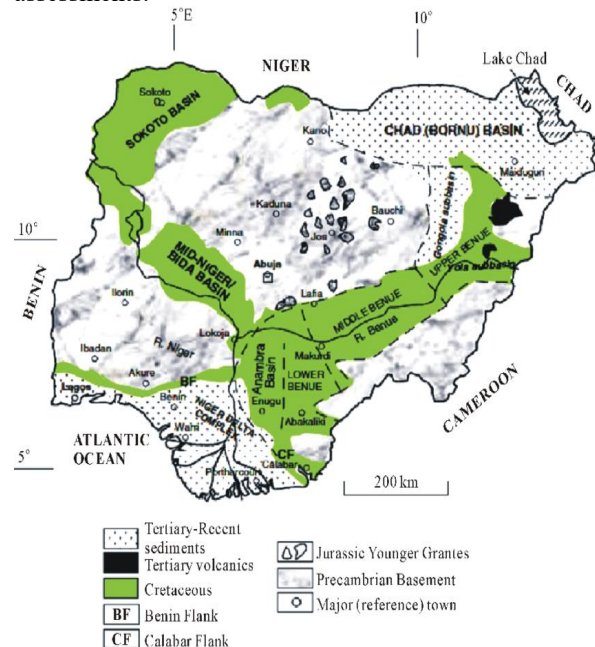


Figure 1: Simplified geological map of Nigeria showing major geological units (Obaje *et al.*, 2020)

Overall, Nigeria's geological hazard profile is complex and multi-dimensional, shaped by interactions among geological structures, climatic conditions, and human activities. A comprehensive review of geological hazards and risk assessment in Nigeria is therefore

essential to support evidence-based planning, disaster risk reduction, and sustainable development initiatives.

2.0 TYPES OF GEOLOGICAL HAZARDS IN NIGERIA

Nigeria experiences a wide range of geological hazards whose spatial distribution, frequency, and impacts are controlled by regional geology, climatic variability, and anthropogenic pressures. Unlike single-hazard environments, the Nigerian landscape is characterized by multi-hazard interactions, where one hazard often triggers or amplifies another. The most prominent geological hazards include landslides, gully and soil erosion, flooding and coastal erosion, drought and desertification, and low-magnitude seismic activity.

2.1 Landslides and Rockfalls

Landslides constitute one of the most destructive geological hazards in Nigeria, particularly in regions with steep slopes, weathered lithologies, and intense rainfall. Although Nigeria is not traditionally classified as a landslide-prone country, recent studies have shown that landslide occurrence is increasing in both frequency and spatial extent, especially in southeastern Nigeria and parts of the northeastern highlands (Igwe & Fukuoka, 2019; Efiog et al., 2020).

Landslides in Nigeria (Table 1) are predominantly rainfall-induced and occur mainly as shallow translational slides, debris flows, and rotational failures. Areas underlain by deeply weathered shales, sandstones, and basement-derived lateritic soils are especially susceptible (Igwe, 2016; Ogunlana *et al.*, 2021). The Abakaliki–Afikpo axis, Enugu escarpment, and parts of Anambra and Imo States have recorded recurrent slope failures associated with prolonged rainfall and poor slope management practices (Igwe, 2014; Nwajide *et al.*, 2020).

Rockfalls are less widespread but occur locally in areas with exposed rock faces, quarry sites, and road cuttings, particularly within the Basement Complex terrains of southwestern and north-central Nigeria. These events are often triggered by excavation activities, intense weathering, and vibrations from traffic or blasting operations (Bonful, 2020; Umar, 2020; Adebola *et al.*, 2022).

The growing expansion of settlements into marginal lands, coupled with deforestation and road construction, has further destabilized slopes, increasing landslide risk. Despite these trends, landslide monitoring and early warning systems remain poorly developed in Nigeria.

Table 1: Summary of Major Landslide-Prone Areas in Nigeria and Controlling Factors

Region	Geological Setting	Topographic Factors	Climatic/Environmental Factors	Anthropogenic Factors
Mambilla Taraba	Plateau, Weathered rocks, intrusions	basement Steep slopes (20–35°), escarpments	High rainfall (>1500 mm/yr), wet season	Agriculture, road cuts, deforestation
Obudu River	Plateau, Cross formations	Shale and sandstone Moderately steep slopes (15–30°)	Intense rainfall, seasonal saturation	Farming on slopes, unregulated settlements
Southeastern Escarpments (Enugu, Ebonyi, Anambra)	Ajali Sandstone, Nanka Formation (sandy, clayey soils)	Incised valleys, steep escarpments	Heavy rainfall, infiltration	water Road construction, urbanization, quarrying
Jos State	Plateau Volcanic basalt and tuff deposits	Moderate to steep slopes (15–25°)	Seasonal heavy rainfall, dry cycles	wet– Mining, slope modifications, settlements
Idanre Hills, Ondo State	Basement rocks (gneiss, schist)	complex Rugged cliff faces	terrain, Rain-induced seepage	saturation, Trail/path excavation, deforestation

2.2 Gully Erosion and Soil Erosion

Gully erosion represents one of the most severe and widespread geological hazards in Nigeria, particularly in the southeastern region (Egboka et al., 2019; Egbueri and Igwe, 2021). It is a geomorphological process involving the rapid incision of deep channels into soil and regolith, often rendering land unusable and threatening infrastructure (Roy, 2023; Taylor, 2001; Igbokwe *et al.*, 2019).

The susceptibility of southeastern Nigeria to gully erosion is linked to a combination of friable sandy

formations, high rainfall intensity, steep slopes, and poor land-use practices. Geological units such as the Nanka Sands, Ajali Sandstone, and Ameki Formation are especially prone to rapid erosion due to their unconsolidated nature and high permeability (Eze & Nwankwoala, 2020; Ogbe and Osokpor, 2021).

Soil erosion, though more diffuse, affects large portions of the country and contributes significantly to land degradation and sedimentation of rivers and reservoirs. In northern Nigeria, wind erosion and sheet erosion dominate, while rill and gully erosion are more

prevalent in the humid south (Igwe, 2012; Abdulkadir *et al.*, 2021).

Human activities such as bush burning, overgrazing, sand mining, and unregulated urban development accelerate erosion processes by removing vegetation cover and altering natural drainage systems. Gully erosion has displaced thousands of people, destroyed farmlands, and imposed heavy economic burdens on affected communities and state governments (Jibo *et al.*, 2020; Onuigbo *et al.*, 2022).

2.3 Flooding and Coastal Erosion

Flooding is the most frequent and geographically extensive hazard in Nigeria, affecting both urban and rural areas (Ologunorisa *et al.*, 2022; Umar and Gray, 2023). It occurs primarily as fluvial flooding along major river systems, pluvial flooding in urban centers, and coastal flooding in low-lying deltaic regions (Aderogba, 2020; Becker *et al.*, 2024).

Riverine flooding is common along the Niger and Benue river systems, where seasonal rainfall, dam releases, and floodplain encroachment combine to

produce recurrent flood events. Urban flooding is increasingly severe in cities such as Lagos, Ibadan, Port Harcourt, and Abuja due to inadequate drainage infrastructure, impervious surfaces, and poor waste management (Ogunbode *et al.*, 2021; Chang and Ross, 2024).

Coastal erosion is a major hazard along Nigeria's Atlantic coastline, particularly within the Niger Delta and Lagos coastal zone. Shoreline retreat, beach erosion, and saltwater intrusion are driven by wave action, tidal dynamics, subsidence, and sea-level rise (Udoh *et al.*, 2019; Abija *et al.*, 2020; Oloyede *et al.*, 2022). The loss of mangroves and coastal wetlands has further reduced natural protection against erosion and storm surges.

Flooding and coastal erosion often interact with other geological hazards by triggering landslides, accelerating erosion, and contaminating groundwater systems, thereby increasing overall disaster risk (Fig. 2).

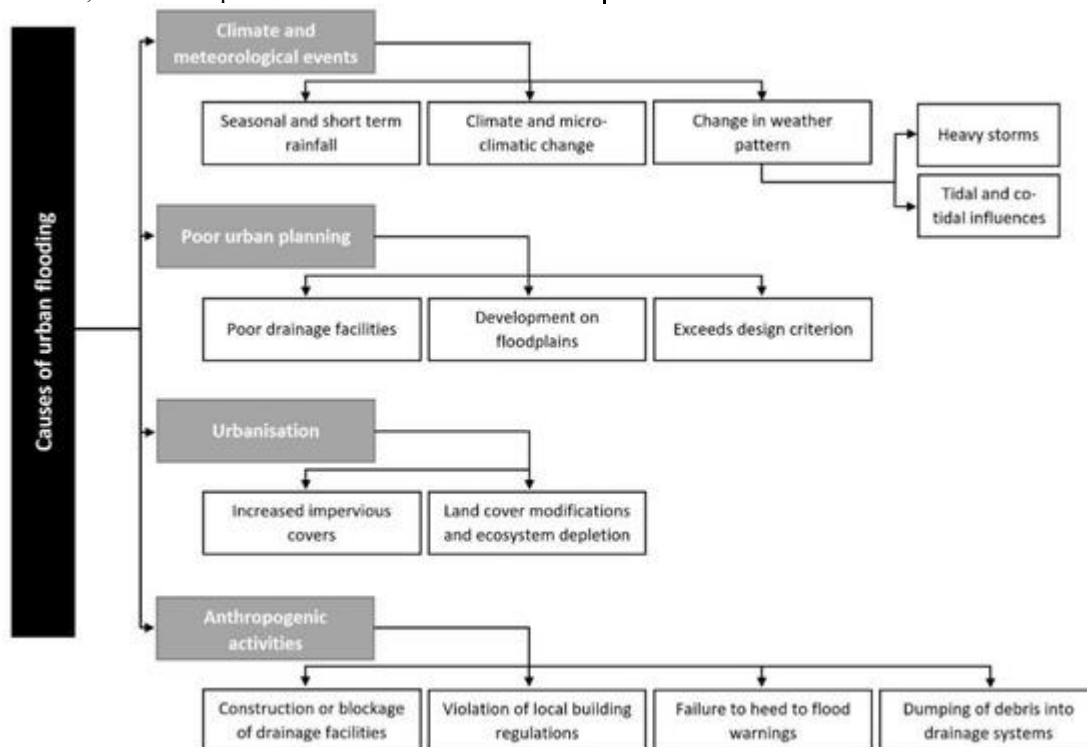


Figure 2: Conceptual interaction between flooding, erosion, and coastal instability in Nigeria

Drought and Desertification

Drought and desertification are dominant geological–environmental hazards in northern Nigeria, particularly within the Sudano–Sahelian ecological zone. Drought is characterized by prolonged periods of rainfall deficit, while desertification refers to land degradation in arid and semi-arid environments resulting from climatic variations and human activities (Olagunju, 2025; Olagunju, 2019).

The geological implications of drought and desertification include soil degradation, reduced groundwater recharge, increased susceptibility to wind erosion, and loss of productive land. Sandy soils and poorly consolidated sedimentary formations in the Chad Basin and Sokoto Basin are particularly vulnerable (Kogbe and Burolet, 1990; Yusuf *et al.*, 2021; Sababa *et al.*, 2023).

Human pressures such as overcultivation, deforestation, fuelwood extraction, and unsustainable irrigation practices exacerbate desertification processes. These hazards have far-reaching socio-economic consequences, including food insecurity, migration, and competition over diminishing natural resources (Abubakar *et al.*, 2020; Ogwu *et al.*, 2024)).

Climate projections suggest that drought frequency and intensity are likely to increase in northern Nigeria, making desertification a critical long-term geological hazard requiring integrated land and water management strategies.

2.4 Seismic Activity and Earth Tremors

Nigeria is generally regarded as a tectonically stable region located within the African Plate; however, recent reports of earth tremors have challenged this perception. Low-magnitude seismic events have been recorded in parts of southwestern Nigeria, the Benue Trough, and north-central regions (Ajakaiye *et al.*, 2018; Olugboji *et al.*, 2021).

These tremors are believed to be associated with reactivated ancient faults, stress accumulation within the Basement Complex, and anthropogenic activities such as mining and reservoir-induced seismicity. Although the magnitudes of recorded events have been relatively low, their occurrence raises concerns about seismic risk in areas with dense populations and vulnerable infrastructure (Antonioni *et al.*, 2007; Salami *et al.*, 2021).

3.0 CAUSES AND CONSEQUENCES OF GEOLOGICAL HAZARDS

Geological hazards in Nigeria arise from a complex interplay between natural earth system processes and increasing human pressure on the environment. While natural factors such as lithology, climate, and geomorphology establish baseline susceptibility, anthropogenic activities significantly intensify hazard frequency, magnitude, and spatial spread.

3.1 Natural Factors Influencing Geological Hazards

Natural geological and environmental conditions play a primary role in determining the spatial distribution and intensity of geological hazards across Nigeria. Lithological composition is a key control, as unconsolidated sediments, highly weathered basement rocks, and clay-rich formations exhibit low shear strength and high erodibility (Hillier, 1995; Adewumi *et al.*, 2020). These properties increase susceptibility to landslides, gully erosion, and ground subsidence, particularly in sedimentary basins and deeply weathered basement terrains.

Climatic factors, especially rainfall intensity, duration, and seasonal variability, are critical drivers of hydro-

geological hazards. High-intensity rainfall events increase pore water pressure, reduce soil cohesion, and trigger slope failures and erosion processes (Elkamhawy *et al.*, 2018; Ogunlela & Oladele, 2021). In contrast, prolonged dry periods promote soil desiccation, crust formation, and wind erosion, particularly in semi-arid regions of northern Nigeria (Idriss *et al.*, 2011; Garba *et al.*, 2019).

Topography and geomorphology also exert strong influence on hazard occurrence. Steep slopes, escarpments, and incised valleys enhance gravitational forces and surface runoff, increasing the likelihood of mass movement and channel erosion. The dissected landscapes of southeastern Nigeria and the highlands of the Mambilla Plateau exemplify terrain-controlled hazard susceptibility (Borokini *et al.*, 2012; Umejiaku *et al.*, 2022).

Additionally, geological structures such as faults, joints, and fractures act as zones of weakness that facilitate slope instability and localized seismic activity. These structures influence groundwater flow paths, weathering patterns, and stress concentration within rock masses (Lawal *et al.*, 2020; Pradhan *et al.*, 2022).

3.2 Human-Induced Factors Exacerbating Geological Hazards

Although natural factors establish hazard potential, human activities are increasingly responsible for the escalation of geological disasters in Nigeria. Rapid urbanization, population growth, and unregulated land-use practices have significantly altered natural landscapes and hydrological systems (Mir *et al.*, 2025; Akinola *et al.*, 2021).

Deforestation is one of the most critical anthropogenic drivers of geological hazards. The removal of vegetation cover reduces soil cohesion, increases surface runoff, and accelerates erosion and landslide processes. Agricultural expansion, logging, and fuelwood harvesting have contributed to extensive land degradation, particularly in southern and northern Nigeria (Macaulay, 2014; Usman & Adefalu, 2019).

Urban development on floodplains, steep slopes, and erosion-prone terrains has increased exposure and vulnerability. Poorly planned road construction, slope cutting, and quarrying activities destabilize slopes and disrupt natural drainage networks, often triggering gully erosion and landslides (Alcántara-Ayala, 2025; Oluwatoyin *et al.*, 2022). In many urban centers, inadequate drainage infrastructure and improper waste disposal exacerbate flooding by obstructing water flow paths.

Mining and sand excavation activities further intensify geological hazards by altering ground stability and



sediment balance. These activities weaken soil and rock structures, promote subsidence, and increase susceptibility to erosion and slope failure (Ibrahim *et al.*, 2020; Zou, 2021). Climate change, though a global phenomenon, acts as a hazard multiplier by increasing the frequency of extreme rainfall events, prolonged droughts, and sea-level rise, thereby amplifying existing geological risks (O'Sullivan, 2015; Niang *et al.*, 2022).

3.3 Economic, Social, and Environmental Impacts

The consequences of geological hazards in Nigeria are far-reaching, affecting economic development, social stability, and environmental sustainability. Economically, geological hazards cause extensive damage to infrastructure such as roads, bridges, buildings, and utility networks, resulting in substantial financial losses. The costs of emergency response, rehabilitation, and reconstruction place significant strain on government resources (Chang *et al.*, 2011; Babangida *et al.*, 2021).

Agriculture, which employs a large proportion of Nigeria's population, is particularly vulnerable. Flooding, erosion, and desertification reduce soil fertility, destroy farmlands, and disrupt agricultural productivity, contributing to food insecurity and rural poverty (Hossain *et al.*, 2020; Sadiq *et al.*, 2020). In coastal and riverine communities, fisheries and aquaculture systems are negatively affected by sedimentation, salinity intrusion, and habitat loss.

Socially, geological hazards lead to displacement, loss of livelihoods, and increased vulnerability of marginalized populations. Communities affected by recurrent hazards often experience reduced access to education, healthcare, and social services, exacerbating existing inequalities (Putsoane *et al.*, 2024; Oluwasegun *et al.*, 2021). In northern Nigeria, drought-induced land degradation has been linked to migration and resource-based conflicts, highlighting the intersection between geological hazards and human security.

Environmentally, geological hazards accelerate land degradation, biodiversity loss, and ecosystem disruption. Gully erosion and flooding degrade river systems through increased sediment loads, while coastal erosion leads to the loss of wetlands and mangrove ecosystems that provide natural hazard buffering (Nichols *et al.*, 2018; Dan-Jumbo *et al.*, 2019). These environmental impacts undermine ecosystem services essential for long-term resilience and sustainable development.

4.0 RISK ASSESSMENT AND MAPPING

Risk assessment and mapping form the core of effective geological hazard management by providing a scientific basis for decision-making, land-use

planning, and disaster risk reduction. In Nigeria, the evolution of hazard risk assessment has progressed from qualitative descriptions toward spatially explicit, data-driven approaches, although significant methodological and institutional gaps remain. This section reviews key components of geological hazard risk assessment, including hazard identification, vulnerability assessment, and risk zoning.

4.1 Hazard Identification and Mapping

Hazard identification involves recognizing and characterizing potentially damaging geological processes, their spatial extent, frequency, and magnitude. In Nigeria, hazard mapping has increasingly relied on remote sensing data, geographic information systems (GIS), and field-based observations to delineate hazard-prone zones (Akodekou *et al.*, 2025; Adebayo & Akintoye, 2020).

Geological hazard maps typically integrate thematic layers such as lithology, slope gradient, drainage density, land use, soil type, and rainfall patterns. For landslide and erosion studies, digital elevation models (DEMs) are commonly used to derive slope, curvature, and aspect parameters, which are combined with rainfall and geological data to identify susceptible areas (Saleem *et al.*, 2019; Ayenew *et al.*, 2019). Flood hazard mapping often incorporates river discharge data, floodplain geometry, and historical flood extents to model inundation scenarios (Olawuni *et al.*, 2021).

Recent Nigerian studies have adopted multi-criteria decision analysis (MCDA) techniques, including the Analytical Hierarchy Process (AHP), to assign weights to hazard-controlling factors. These methods allow for systematic evaluation of hazard susceptibility, particularly in data-scarce environments (Dragičević *et al.*, 2015; Ojo *et al.*, 2022). However, hazard maps in Nigeria are frequently developed at local or regional scales, limiting their applicability for national-level planning.

4.2 Vulnerability Assessment

Vulnerability assessment (Table 2) focuses on evaluating the susceptibility of exposed elements—such as populations, infrastructure, and economic assets—to damage from geological hazards. Unlike hazard mapping, which emphasizes physical processes, vulnerability assessment incorporates socio-economic, structural, and institutional dimensions (Birkmann *et al.*, 2022).

In Nigeria, vulnerability is strongly influenced by settlement patterns, building standards, income levels, and access to basic services. Informal settlements located on floodplains, unstable slopes, and erosion-prone terrains exhibit high vulnerability due to poor construction quality and limited coping capacity (Begum, 2025; Ajibade *et al.*, 2020). Critical

infrastructure, including roads, bridges, power facilities, and water supply systems, is often inadequately designed to withstand geological hazards.

Recent approaches to vulnerability assessment in Nigeria have utilized composite indices that integrate demographic data, housing characteristics, and livelihood dependence. These indices are spatially analyzed using GIS to identify high-risk communities (Awolala *et al.*, 2022; Olawoye & Akinyemi, 2019).

Despite these advances, vulnerability assessments remain constrained by limited census data resolution, lack of asset inventories, and weak institutional coordination.

Furthermore, vulnerability is dynamic and changes over time due to urban growth, climate variability, and socio-economic transitions. Static vulnerability assessments therefore underestimate long-term risk, underscoring the need for continuous monitoring and updating.

Table 2: Key Indicators Commonly Used in Geological Vulnerability Assessment in Nigeria

Indicator Category	Specific Indicators	Description / Relevance
Demographic Vulnerability	Population density, age distribution, household size	High population density and presence of vulnerable groups (children, elderly) increase exposure to hazards
Socio-Economic Status	Income level, poverty rate, employment type, livelihood dependence	Low-income communities have limited capacity to cope with hazard impacts
Housing & Infrastructure	Building material and quality, road network, bridges, drainage systems	Poor construction quality and inadequate infrastructure increase susceptibility to damage
Land Use & Land Cover	Urbanization level, vegetation cover, impervious surface fraction	Land-use practices affect runoff, slope stability, and erosion susceptibility
Access to Services	Proximity to hospitals, emergency services, water supply, electricity	Communities with limited access are more vulnerable during hazard events
Environmental Sensitivity	Soil type, slope gradient, drainage density, proximity to rivers/coastlines	Geophysical and environmental characteristics that control hazard severity and exposure
Institutional Governance	Disaster preparedness plans, early warning systems, policy enforcement	Effective governance reduces vulnerability; absence increases risk

4.3 Risk Mapping and Zoning

Risk mapping integrates hazard probability and vulnerability to produce spatial representations of potential loss and damage. Risk maps serve as critical tools for land-use zoning, infrastructure planning, and disaster preparedness (Koks *et al.*, 2019).

In the Nigerian context, risk zoning has been applied mainly in flood-prone urban areas and erosion-affected regions. Risk zones are typically classified into low, medium, and high-risk categories based on hazard intensity and exposure levels. These classifications inform decisions such as development restrictions, relocation priorities, and engineering intervention requirements (Adeleye *et al.*, 2021).

Probabilistic risk assessment methods, which estimate the likelihood of hazard occurrence and expected losses over time, are increasingly recognized as essential for comprehensive risk mapping. However, their application in Nigeria remains limited due to insufficient long-term hazard data and modeling capacity (Mensah *et al.*, 2020). Consequently, most risk maps rely on deterministic or semi-quantitative approaches.

The integration of geospatial technologies, including satellite imagery, unmanned aerial vehicles (UAVs), and spatial modeling tools, has improved the accuracy

of risk maps in recent years. Nonetheless, challenges such as data accessibility, technical expertise, and institutional fragmentation hinder the mainstreaming of risk mapping into national development planning (Ogunniyi *et al.*, 2022).

5.0 CASE STUDIES OF GEOLOGICAL HAZARDS IN NIGERIA

Case studies provide empirical evidence of how geological hazards manifest under specific environmental and socio-economic conditions. In Nigeria, documented hazard events reveal recurring patterns of vulnerability, governance challenges, and gaps between scientific knowledge and practical risk management. This section reviews selected case studies representing major hazard types and regions.

5.1 Gully Erosion in Southeastern Nigeria

Southeastern Nigeria represents one of the most severely gully-eroded landscapes in West Africa (Fig. 3). States such as Anambra, Imo, Abia, and Enugu have recorded thousands of active gullies, many exceeding several meters in depth and width. Studies conducted after 2018 identify the interaction of fragile sandy formations, intense rainfall, and anthropogenic land disturbance as key drivers of gully initiation and expansion (Belayneh *et al.*, 2022; Okeke *et al.*, 2019).

The Nanka Formation and Ajali Sandstone, which dominate much of the region, are composed of poorly consolidated sands with low cohesion and high permeability. These properties facilitate rapid infiltration and subsurface erosion, leading to gully head retreat and slope collapse (Dunne, 1990; Ocheli *et al.*, 2020). Road construction without adequate drainage and the concentration of runoff from urban surfaces further accelerate gully development.

The socio-economic impacts of gully erosion in southeastern Nigeria are severe. Entire communities have been displaced, farmlands lost, and transportation

networks disrupted. In some cases, gully systems have cut off access to schools, markets, and healthcare facilities, exacerbating rural poverty (Aseyan *et al.*, 2022; Egboka *et al.*, 2021).

Intervention efforts, including the Nigeria Erosion and Watershed Management Project (NEWMAP), have achieved localized success through engineering controls and revegetation. However, studies indicate that long-term sustainability depends on community involvement, maintenance, and catchment-scale planning rather than site-specific interventions alone (Spray *et al.*, 2022; Ojukwu *et al.*, 2022).



Figure 3: Typical gully erosion morphology in southeastern Nigeria

5.2 Flooding in Southwestern Nigeria

Southwestern Nigeria, particularly Lagos, Ogun, and Oyo States, experiences recurrent and increasingly severe flooding events (Table 3). These floods are predominantly pluvial and fluvial, resulting from intense rainfall, urban surface sealing, and inadequate drainage infrastructure (Adegun, 2023; Adelekan & Fregene, 2019).

Lagos, as a low-lying coastal megacity, is especially vulnerable due to its complex lagoonal system, high population density, and extensive informal settlements. Studies using satellite-derived flood extent mapping have shown a steady expansion of flood-prone zones in metropolitan Lagos between 2018 and 2022 (Adegun, 2023; Balogun *et al.*, 2021).

The impacts of flooding in southwestern Nigeria include loss of lives, damage to residential and commercial properties, disruption of transportation, and contamination of water supplies. Flood events also disproportionately affect low-income communities located in floodplains and wetlands, highlighting strong socio-spatial inequality in flood risk distribution (Bosisio and Moreno-Jiménez, 2022; Ajayi *et al.*, 2020).

Despite the availability of flood hazard maps, their integration into urban planning remains limited. Structural measures such as channelization and drainage expansion have often been implemented without addressing upstream runoff generation and land-use control, leading to repeated flood losses (Juan-Diego *et al.*, 2025; Ogunyemi *et al.*, 2022).

Table 3: Major Flood Events in Southwestern Nigeria since 2018 and Reported Impacts

Year	State(s) Affected	Cause / Trigger	Reported Impacts
2018	Lagos, Ogun	Heavy rainfall, inadequate drainage, urbanization	10 fatalities, displacement of >15,000 people, property and infrastructure damage
2019	Oyo, Lagos	Intense rainfall, river overflow	Flooded farmlands, road closures, 5 deaths, damage to residential and commercial areas
2020	Lagos, Ondo	Pluvial flooding, blocked drainage channels	Displacement of ~20,000 people, loss of household assets, disruption of transport
2021	Ogun, Lagos	Riverine and pluvial flooding due to combined rainfall and dam releases	Widespread property damage, power outages, 12 deaths, economic losses estimated at ~\$15 million
2022	Lagos, Oyo, Ogun	Torrential rainfall, inadequate urban planning	Flooding of low-lying communities, destruction of roads and bridges, disruption of markets
2023	Lagos, Ogun, Oyo	Intense rainfall coupled with poor drainage maintenance	Over 25,000 displaced, severe infrastructural damage, contamination of water supply

5.3 Landslides in Nigeria's Mountainous Regions

Although landslides are less widespread than erosion and flooding, notable events have been recorded in Nigeria's mountainous and high-relief areas, including the Mambilla Plateau, Obudu Plateau, and parts of southeastern escarpments. Landslide occurrences in these regions are primarily rainfall-induced and involve shallow soil slips and debris flows (Joshua *et al.*, 2025; Dahiru *et al.*, 2020).

The Mambilla Plateau, underlain by weathered basement rocks and volcanic formations, has experienced slope failures linked to prolonged rainfall and agricultural modification of steep slopes. Terracing, road cuts, and deforestation have reduced slope stability, increasing landslide susceptibility (Osman, 2018; Abdullahi *et al.*, 2021).

In southeastern Nigeria, landslides often occur in association with gully systems, where undercutting and saturation weaken slope materials. These events pose significant risks to rural settlements and transportation corridors (Osumborogwu, 2021; Nwosu *et al.*, 2019).

Landslide risk management in Nigeria is constrained by limited monitoring, absence of early warning systems, and lack of landslide inventories. Most documented cases are reported after damage has occurred, indicating a reactive rather than preventive approach (Wadhawan, 2018; Yakubu *et al.*, 2022).

6.0 MITIGATION AND MANAGEMENT STRATEGIES

Mitigation and management strategies (Table 4) are central to reducing the impacts of geological hazards and enhancing resilience in hazard-prone environments. In Nigeria, mitigation approaches have

evolved over time from predominantly reactive interventions to a growing emphasis on integrated disaster risk reduction and sustainable land management. Effective mitigation requires a combination of structural and non-structural measures, supported by community participation and strong institutional frameworks.

6.1 Structural Measures (Engineering Solutions)

Structural mitigation measures involve physical and engineering interventions designed to control, reduce, or eliminate the impacts of geological hazards. In Nigeria, such measures are commonly applied to erosion control, flood management, and slope stabilization (Oyebode, 2021; Chukwu *et al.*, 2019).

For gully erosion, engineering solutions include the construction of check dams, retaining walls, drop structures, and lined drainage channels. These structures are intended to reduce runoff velocity, stabilize gully heads, and prevent further incision. Studies conducted in erosion-prone areas of southeastern Nigeria indicate that integrated engineering designs combining hard structures with slope regrading are more effective than isolated interventions (Ene and Okogbue, 2014; Nwachukwu *et al.*, 2021).

Flood mitigation infrastructure includes drainage expansion, river channel dredging, levees, and embankments. In urban centers such as Lagos and Ibadan, stormwater management systems have been implemented to reduce flood frequency; however, their effectiveness is often compromised by poor maintenance and rapid urban expansion (Daigneault *et al.*, 2016; Adeloye & Rustum, 2020). Coastal protection measures, including groynes, revetments,

and seawalls, have been employed to address shoreline erosion, though these sometimes result in sediment redistribution and downstream erosion if not properly designed (Nordstrom, 2014; Akanmu *et al.*, 2022). Slope stabilization measures for landslide-prone areas include terracing, soil nailing, retaining structures, and

controlled drainage. While these techniques have proven effective in localized settings, their application in Nigeria remains limited due to high costs and technical capacity constraints.

Table 4: Common Structural Mitigation Measures for Major Geological Hazards in Nigeria

Geological Hazard	Structural Mitigation Measures	Purpose / Function
Gully Erosion	Check dams, retaining walls, lined drainage channels, slope regrading	Reduce runoff velocity, stabilize gully heads, prevent further incision
Flooding (Urban & Riverine)	Drainage expansion, river channel dredging, levees and embankments, stormwater retention basins	Control water flow, prevent inundation, reduce flood peaks
Coastal Erosion	Groynes, revetments, seawalls, beach nourishment	Protect shorelines, prevent land loss, reduce sediment redistribution
Landslides & Slope Failures	Soil nailing, terracing, retaining structures, controlled drainage	Stabilize slopes, prevent soil displacement, reduce landslide risk
Desertification / Drought-induced erosion	Sand fences, check dams, windbreaks, contour bunding	Reduce wind/surface runoff erosion, conserve soil moisture
Seismic Risk (low-magnitude tremors)	Earthquake-resistant building design, reinforced foundations, retrofitting existing structures	Minimize structural failure and collapse during tremors

6.2 Non-Structural Measures (Policy, Planning, and Education)

Non-structural measures focus on reducing vulnerability and exposure through policy instruments, land-use planning, institutional strengthening, and public awareness. These measures are increasingly recognized as cost-effective and sustainable components of geological hazard management (Yadawa, 2024; Wisner *et al.*, 2021).

Land-use planning and zoning regulations play a critical role in hazard mitigation by restricting development in high-risk areas such as floodplains, unstable slopes, and erosion-prone terrains. In Nigeria, the enforcement of such regulations remains weak, with many hazard-prone areas continuing to experience unplanned development (Offia, 2011; Ogunleye *et al.*, 2019). Environmental Impact Assessments (EIAs) are legally required for major projects, but their effectiveness is often undermined by inadequate geological hazard considerations.

Early warning systems and disaster preparedness plans constitute another key non-structural approach. Flood forecasting and warning initiatives led by national agencies have improved short-term preparedness in some regions, but coverage and reliability remain inconsistent (Emerton *et al.*, 2016; Adebimpe *et al.*, 2021). For other geological hazards such as landslides and erosion, early warning systems are largely absent.

Education and capacity building are essential for improving hazard awareness and promoting risk-informed decision-making. Integrating geological hazard education into school curricula and professional training programs has been identified as a long-term

strategy for building societal resilience (Righi *et al.*, 2021; Olatunbosun & Bello, 2022).

6.3 Community-Based Approaches

Community-based approaches emphasize the involvement of local populations in hazard mitigation planning, implementation, and monitoring. These approaches recognize local knowledge, social networks, and adaptive practices as critical components of effective risk reduction (Kettle *et al.*, 2014; Mercer *et al.*, 2019).

In Nigeria, community participation has been particularly important in erosion control and flood management projects. Local initiatives such as tree planting, maintenance of drainage channels, and regulation of land-use practices have contributed to hazard reduction in several rural and peri-urban communities (Adefisoye, 2017; Ezechi *et al.*, 2020). Community-driven monitoring of erosion sites has also improved early detection of hazard escalation.

However, community-based strategies face challenges related to limited financial resources, technical expertise, and institutional support. Successful programs are typically those that integrate community efforts with government-led interventions and provide sustained technical guidance and funding (Wahid *et al.*, 2017; Ishaku *et al.*, 2021).

Overall, mitigation and management strategies in Nigeria remain uneven across hazard types and regions. While structural measures address immediate physical risks, non-structural and community-based approaches offer more sustainable pathways for reducing long-term vulnerability. An effective national geological hazard mitigation framework therefore requires coordinated implementation of these complementary strategies.

7.0 CHALLENGES AND OPPORTUNITIES

Despite growing recognition of geological hazards as major development constraints in Nigeria, efforts to assess, mitigate, and manage these hazards continue to face significant challenges. At the same time, emerging technological, institutional, and societal developments present opportunities to improve geological hazard risk reduction. This section critically examines key challenges and identifies pathways for progress.

7.1 Data Limitations and Infrastructure Constraints

One of the most significant challenges in geological hazard assessment and management in Nigeria is the persistent lack of reliable, high-resolution data. Comprehensive geological, geotechnical, hydrological, and climatological datasets required for hazard modeling and risk analysis are often incomplete, outdated, or inaccessible (Rejaur *et al.*, 2025; Ogunniyi & Olayinka, 2019).

Limited availability of long-term monitoring data hampers the development of probabilistic hazard models, particularly for floods, landslides, and seismic activity. Many hazard assessments rely on short-term datasets or post-event observations, which restrict their predictive capability (Ce, 2018; Afolayan *et al.*, 2020). In addition, the sparse distribution of hydrometeorological stations and geophysical monitoring networks reduces the accuracy of early warning systems.

Infrastructure constraints further exacerbate vulnerability. Aging drainage systems, poorly maintained erosion control structures, and inadequate urban infrastructure increase exposure to hazards. In rural areas, limited access to engineering expertise and financial resources constrains the implementation of effective mitigation measures (Consoer and Milman, 2018; Salihu *et al.*, 2021).

However, recent investments in satellite-based data acquisition, open-access geospatial datasets, and low-cost sensor technologies present opportunities to address data gaps. The increasing availability of remotely sensed rainfall, elevation, and land-use data offers significant potential for improving hazard monitoring and assessment (Metternicht *et al.*, 2005; Mutanga *et al.*, 2020).

7.2 Policy and Institutional Framework

Institutional fragmentation and weak policy enforcement remain major obstacles to effective geological hazard management in Nigeria. Responsibilities for disaster risk reduction are distributed across multiple agencies at federal, state, and local levels, often resulting in overlapping

mandates and poor coordination (Akinwale & Adegboye, 2021; Okunola, 2025).

Although Nigeria has national disaster management policies and environmental regulations, their implementation is frequently undermined by limited technical capacity, insufficient funding, and political interference. Geological hazard considerations are rarely integrated into development planning, infrastructure design, and land allocation processes (Fell *et al.*, 2008; Ojo & Alao, 2019).

Furthermore, the absence of a comprehensive national geological hazard database limits evidence-based policymaking. Hazard assessments conducted by academic institutions and development projects are often not systematically incorporated into government decision-making frameworks.

Nevertheless, recent policy reforms emphasizing disaster risk reduction, climate adaptation, and sustainable land management offer opportunities for institutional strengthening. Aligning geological hazard management with national development strategies and climate policies could enhance coherence and effectiveness (Ishola *et al.*, 2022; Swaris *et al.*, 2024).

7.3 Public Awareness and Education

Low levels of public awareness and understanding of geological hazards significantly contribute to vulnerability in Nigeria. Many communities lack basic knowledge of hazard triggers, early warning signs, and appropriate response measures (Garcia and Fearnly, 2024; Adebayo *et al.*, 2021). This knowledge gap is particularly evident in informal settlements and rural areas, where hazard exposure is often highest.

The limited integration of geological hazard education into formal school curricula and professional training programs further constrains risk reduction efforts. As a result, engineers, planners, and policymakers may lack adequate training in hazard-sensitive design and land-use planning (Motamed *et al.*, 2020; Olatunji & Salami, 2020).

However, increasing access to digital communication platforms and community-based outreach programs provides opportunities to enhance hazard awareness and education. Mobile technology, social media, and local radio have been successfully used in some regions to disseminate early warning information and promote preparedness (Adesina *et al.*, 2022; Marsh *et al.*, 2024).

8.0 CONCLUSION

This review has synthesized current knowledge on geological hazards and risk assessment in Nigeria, highlighting the complex interplay of natural processes and human-induced factors that contribute to hazard occurrence and impact. The evidence demonstrates that

Nigeria experiences a diverse range of geological hazards—including landslides, gully erosion, flooding, coastal erosion, drought, desertification, and low-magnitude seismic activity—whose spatial distribution is strongly influenced by lithology, topography, climatic variability, and anthropogenic pressures.

A critical observation from the review is that while natural factors such as rainfall intensity, slope gradient, and soil type set the baseline susceptibility, human activities—including deforestation, unplanned urbanization, poor land-use practices, and mining—significantly exacerbate the frequency and severity of geological hazards. The socio-economic consequences are profound, ranging from the destruction of infrastructure and agricultural lands to displacement, loss of livelihoods, and environmental degradation. These impacts disproportionately affect vulnerable populations, reinforcing existing social inequalities and constraining sustainable development.

Risk assessment and mapping have emerged as essential tools for understanding hazard exposure and guiding mitigation strategies. Advances in geospatial technologies, GIS, and remote sensing have improved hazard identification and vulnerability assessment, yet national coverage remains uneven, and probabilistic risk models are rarely applied at scale. Effective mitigation in Nigeria requires an integrated approach that combines structural interventions—such as slope stabilization, drainage systems, and coastal protection—with non-structural measures, including policy enforcement, land-use planning, early warning systems, and public education. Community-based approaches are increasingly recognized as essential for sustaining mitigation efforts and enhancing local adaptive capacity.

Despite these advances, challenges remain. Data limitations, weak institutional coordination, policy enforcement gaps, and low public awareness continue to undermine effective hazard management. Conversely, emerging opportunities—including advances in geospatial monitoring, policy reform, and community engagement—offer pathways to enhance geological hazard resilience. Addressing these challenges requires a holistic and multi-level approach that integrates scientific knowledge, governance, and societal participation.

FUTURE RESEARCH DIRECTIONS

Despite progress in understanding geological hazards in Nigeria, significant gaps in knowledge, technology, and implementation remain. Future research should focus on integrating geospatial technologies and machine learning for improved hazard prediction and susceptibility mapping, developing multi-hazard early warning systems that combine real-time monitoring with community participation, and enhancing

community engagement through structured risk communication and indigenous knowledge. Additionally, studies should examine the interactions between climate change and geological hazards to inform scenario-based planning and resilient infrastructure design. Policy-oriented and interdisciplinary research is also critical, linking scientific insights with governance, land-use planning, and mitigation strategies to achieve sustainable and socially acceptable hazard management.

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