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Integrated Erosion Risk Assessment in Imo State, Nigeria: A GIS-Based Multi-Criteria and Socio-Economic Analysis

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Abstract

Imo State in southeastern Nigeria has over 780 active erosion sites, slowly swallowing farmlands and homes. While experts know the causes, soft soils, heavy rains exceeding 2,500 mm yearly, and fast urban growth, few studies have linked physical danger to people's real struggles. This study maps erosion risk using satellite data and conversations with nine severely impacted communities including Nekede and Amucha. The study found that cities like Owerri face the highest danger because paved surfaces push water into vulnerable areas. In western districts like Oguta, crowded land and natural drainage patterns worsen the crisis. Farmers, who make up 70 percent of the population, have lost about one fifth of their arable land, threatening food security. This work gives local leaders a practical tool to protect lives and livelihoods before more land disappears.

Keywords: *Gully Erosion, Geospatial Analysis (GIS), Socio-Economic Vulnerability, Imo State, Multi-Criteria Decision Analysis (MCDA).*

1. Introduction

Sustainable land management means keeping soil healthy for farming, protecting roads and homes, and helping communities feel secure on their land (UNEP, 2021). For Imo State, a region blessed with fertile soils and many people, this ideal calls for smart, evidence-based planning. That means using hazard risk maps to guide development, protect livelihoods, and build a future aligned with the Sustainable Development Goals (UNDP, 2023). But the reality in Imo State is frightening. The state sits at the heart of Nigeria's "erosion gully belt" in the Southeast and faces a rapidly worsening crisis. A recent study using satellite images found more than 780 active gully sites in Imo. Some large gullies, like the Nekede and Obinze complexes near Owerri, grow by over 30 meters each year (Okeukwu *et al.*, 2024; Obiorah *et al.*, 2025). This destruction comes from nature and human actions combined. The ground beneath is made of loose, unconsolidated sands and gravels from the Benin Formation and weak shales from the Imo Shale Formation, both easily washed away (Ofomata, 1985). This fragile geology meets one of Nigeria's highest yearly rainfall totals, exceeding 2,500 millimeters, made worse by intense land use pressure. Cutting down forests for farms and cities has reduced tree cover to less than 10 percent in many parts of the state, removing nature's protection (Uzonu and Nzeako, 2024). Farming on slopes without terracing, uncontrolled sand mining, and poor drainage planning in growing cities like Owerri and Orlu have critically destabilized the land (Nwankwoala and Igbokwe, 2019).

The damage to people, the economy, and the environment is severe. An estimated 20 percent of the state's farmland has been badly damaged or lost, directly threatening food security in a region where more than 70 percent of people depend on farming and agricultural trade for survival (Aja *et al.*, 2024). Major roads, including parts of the Owerri Onitsha highways, are under constant threat, disrupting trade (Obianeri, 2025). More than 50 communities have been partly or fully displaced, including Amator, Irette, and Umuagu Isu, creating a growing group of people forced to leave their homes (Ezeomedo and Igbokwe, 2023). Each year, the state and federal governments spend billions of Naira on reactive gully repair projects that often fail, money that could have gone to other urgent needs (World Bank, 2021). Several local studies have looked at parts of the erosion problem, but they have serious limits. The early landmark work by Ofomata (1985) gave a regional view of the landscape but lacked the detailed, state wide spatial analysis that modern mapping tools allow. Igbokwe *et al.* (2008) used aerial photos to map gullies in parts of Imo but did not combine multiple hazard factors or use high resolution satellite images. Other studies, such as Emenike and Ogbuagu (2014), focused on specific things like soil properties in small areas but did not produce a risk map for the whole state. Azuka *et al.* (2021) created a useful list of gully sites but stopped short of a full risk assessment that links physical hazards to the lives of local people. So, a critical gap remains. There is no unified, state wide erosion risk assessment that combines updated hazard modelling, a careful inventory of what is vulnerable, and an integrated analysis of risk to guide targeted action.

Looking at the broader research landscape, studies on erosion have taken different paths. Some researchers aim to establish basic methods and principles. Moore *et al.* (1991) focused on using digital terrain modeling to predict water flow and landscape changes. Wilson and Gallant (2000) gave a broad overview of terrain analysis applications. Morgan (2005) outlined global soil erosion problems and conservation solutions. Kirkby (1987) aimed to model the complex relationships between erosion, landslides, and valley formation at the scale of river basins. A second group has more specific, process focused goals. Le Bissonnais and Singer (1992) ran experiments to understand how soil water content and rainfall patterns affect crusting, runoff, and erosion. Nearing *et al.* (2005) tested how well erosion models predict changes in response to shifting rainfall and land cover. A third group works on applied and method development goals. Renard *et al.* (1997) developed and standardized the Revised Universal Soil Loss Equation as a guide for conservation planning. Mitasova *et al.* (1996) and Bewket and Teferi (2009) both built GIS based approaches, the former for modeling topographic potential and the latter for assessing hazard and prioritizing treatment at a watershed level. Pourghasemi and Rahmati (2018), though focused on landslides, compared how well different predictive algorithms perform.

The methods across these studies vary widely. Moore *et al.* (1991), Morgan (2005), and Wilson and Gallant (2000) used reviews to summarize existing knowledge. Le Bissonnais and Singer (1992) ran controlled experiments. Kirkby (1987) and Nearing *et al.* (2005) used computer models. Renard *et al.* (1997) developed RUSLE through careful field work. Mitasova *et al.* (1996) and Bewket and Teferi (2009) used GIS as their main tool. Pourghasemi and Rahmati (2018) compared multiple machine learning algorithms. The progression is clear, moving from literature reviews to experiments to spatial analysis. The findings vary too but consistently affirm the importance of physical factors. The review-based studies produced general insights. Moore *et al.* (1991) found that digital terrain modeling is a valuable predictive tool. Morgan (2005) concluded that soil erosion is a serious global problem solvable with conservation. Wilson and Gallant (2000) confirmed that terrain analysis helps us understand landscape processes. The experimental and applied studies gave specific, measurable results. Le Bissonnais and Singer (1992) found that a 20 percent increase in soil water content could raise runoff by 15 percent. Renard *et al.* (1997) affirmed RUSLE accuracy, later noted to exceed 70 percent in many applications. Bewket and Teferi (2009) found their watershed was highly prone to erosion and needed prioritization. Mitasova *et al.* (1996) confirmed that GIS could accurately predict erosion risk. Pourghasemi and Rahmati (2018) showed algorithm performance varied widely, from 70 to 85 percent accuracy. Kirkby (1987) showed erosion and landslides strongly influence how river basins evolve.

Research on inland erosion has followed a clear path. Early work, such as Dengiz *et al.* (2009) in Turkey, aimed to apply GIS and the Universal Soil Loss Equation to map areas of high erosion potential. These studies validated geospatial tools for finding physical hotspots but lacked a careful look at human impact. A major shift came with Hasanuzzaman *et al.* (2024), who set out to model social vulnerability to riverbank erosion along the Ganga River in India. Their goal was to identify which communities were least able to cope, not just where the riverbank was most unstable. Their method layered socioeconomic data including literacy rates, access to credit, and household assets onto physical factors. A critical finding was that a community's ability to adapt could significantly lower its overall risk.

This integrated philosophy is echoed by González Morales *et al.* (2018), who linked soil erosion vulnerability to poverty in Mexico, and by Ekere and Udoh (2014) in their multi hazard assessment. The central recommendation from these inland erosion studies is the need to combine physical science with social science. Spending money based only on physical susceptibility may fail to protect the most vulnerable people. When we examine the inland erosion literature, a clear agreement emerges. Modern erosion risk is a social and ecological issue. Researchers use advanced geospatial methods and affirm that social vulnerability is a main driver of disaster outcomes. Yet a significant gap remains. There is no unified assessment framework designed for regions that suffer from gully erosion in southeastern Nigeria, where impacts mirror the social and economic devastation seen elsewhere.

This gap is especially urgent for southeastern Nigeria, which suffers catastrophic gully erosion. The existing literature provides useful templates, but none have been synthesized and applied to this specific context (Stathopoulos *et al.*, 2017; Ekere and Udoh, 2014). The physical drivers are well studied locally, but integration with detailed spatial analysis of social vulnerability is missing. Therefore, a critical research need is to develop a holistic vulnerability model for southeastern Nigeria. Such a study would address a dire local need and contribute to the broader field by demonstrating how integrated vulnerability frameworks can be adapted for complex inland erosion environments.

2. Aim and Objectives

This study aims to conduct a GIS based erosion risk assessment in Imo State, Nigeria, by integrating physical and socioeconomic vulnerability factors to map high risk areas and guide mitigation strategies. It also seeks to assess the implications of erosion risk for vulnerable communities.

3. Materials and Methods

3.1 Study Area

Imo State lies in southeastern Nigeria between latitudes 4°45'N and 7°15'N and longitudes 6°50'E and 7°25'E. It shares borders with Abia, Anambra, Rivers, and Delta States, with Owerri as its capital. Covering about 5,100 square kilometers, it sits within the oil rich Niger Delta, a location that fuels informal trade and commerce. Its proximity to commercial hubs like Port Harcourt strengthens its role in urban economic development (Adebayo and Olawale, 2023; Udoh and Akpan, 2020). The state's lush tropical rainforest includes dense forests, oil palm plantations, and mangrove swamps near Rivers State. This vegetation supports farming, logging, and crafts. But deforestation and poor farming practices have brought environmental harm, threatening local biodiversity (Gabriel and Umoh, 2025; Akinola and Bello, 2024). Protecting this landscape through sustainable land use is essential for preserving nature and keeping the ecosystem balanced for generations to come.

Figure 1: Map of Imo State

Source: Research Compilations from GIS Unit, University of Uyo, 2025

3.2 Methods

This research used a mixed methods approach, combining geospatial mapping with secondary socioeconomic data to study erosion in Imo State. Physical factors such as slope, drainage, land use, and soil properties were analyzed using a soil map from the Food and Agriculture Organization, 2024 Landsat images from the US Geological Survey, and Digital Elevation Models for topographic derivatives. To understand community vulnerability, focus group discussions were held across nine severely affected communities: Nekede, Ihiagwa, Avuvu, Ubomiri, Umunwanwa, Amucha, Isunjaba, Awo Omamma, and Obokwe. These nine Local Government Areas were purposively selected because residents had direct experience with erosion, including land loss, housing destruction, road damage, and failed repairs. A Garmin handheld GPS device recorded precise locations, while transcripts captured personal stories. Secondary data from government archives and online databases added context.

All physical factor layers were brought into a common projection and resolution within a GIS environment. They were combined through a multi criteria decision approach, allowing the study to assign relative weights to different hazards. Field observations documented erosion severity, length, and specific impact sites. This triangulation of numbers and narratives ensured a full and grounded understanding of where erosion hits hardest and who suffers most. The approach prioritized real community voices alongside scientific measurement to guide targeted, compassionate policy responses.

4. Results and Findings

4.1 Mapping and Characterization of Hazard Elements

This hazard mapping aims to identify and spatially delineate areas susceptible to soil erosion by integrating key factors LULC, Slope, Drainage, Soil, Elevation, and Rainfall using GIS and weighted multi-criteria analysis. The objective is to produce a standardized hazard zonation map to guide land-use planning, prioritize mitigation measures, and inform risk-reduction strategies, thereby supporting sustainable development and community resilience in the study area.

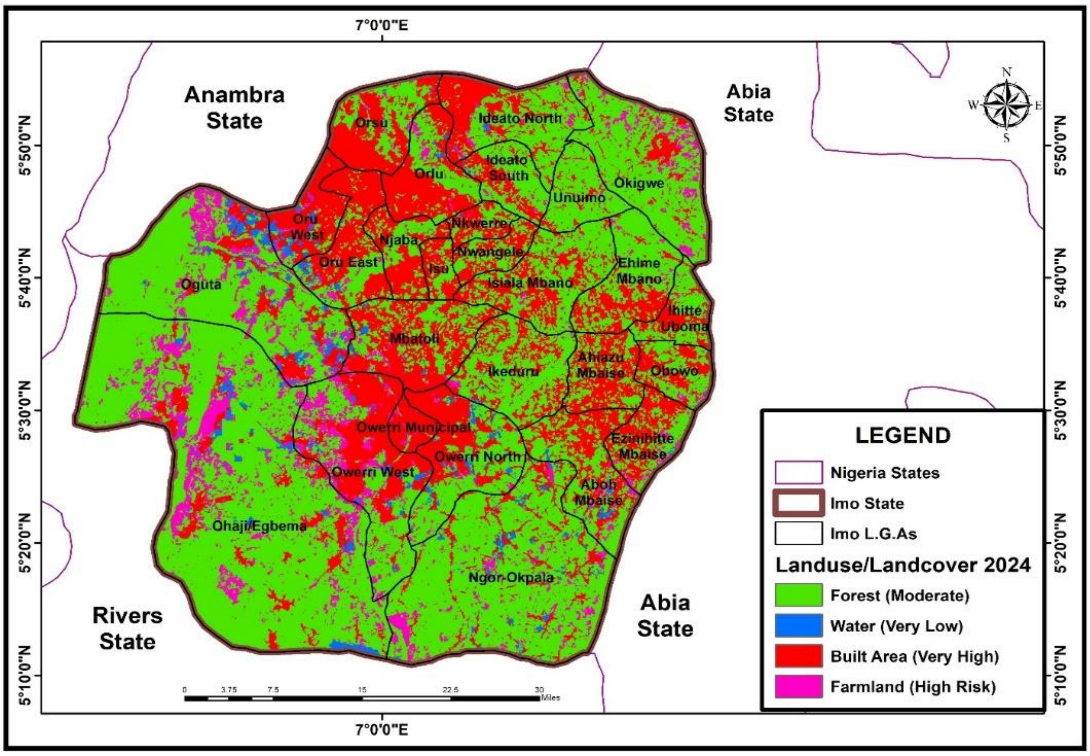

Figure 2: Land Use Land Cover Map of Imo State
Source: Researcher's Compilation from GIS Lab – University of Uyo 2025

The Landuse Landcover map reveals how human activity shapes erosion risk across Imo State. Built areas shown in red face very high risk because paved surfaces block water from soaking into the ground, forcing runoff to rush across the land with enough force to carve deep gullies. These red zones cluster tightly around Owerri, the state capital, and stretch along major roads into commercial centers like Orlu. Farmland shown in pink is also widespread and carries high risk. While growing crops offer some protection, the soil lies bare and loose during plowing and planting, leaving it vulnerable to heavy rains. In contrast, forests shown in yellowish green and water bodies shown in blue offer low to very low risk. These natural buffers dominate quieter local government areas like Ohaji Egboma in the south, where the land remains better protected and erosion is less severe.

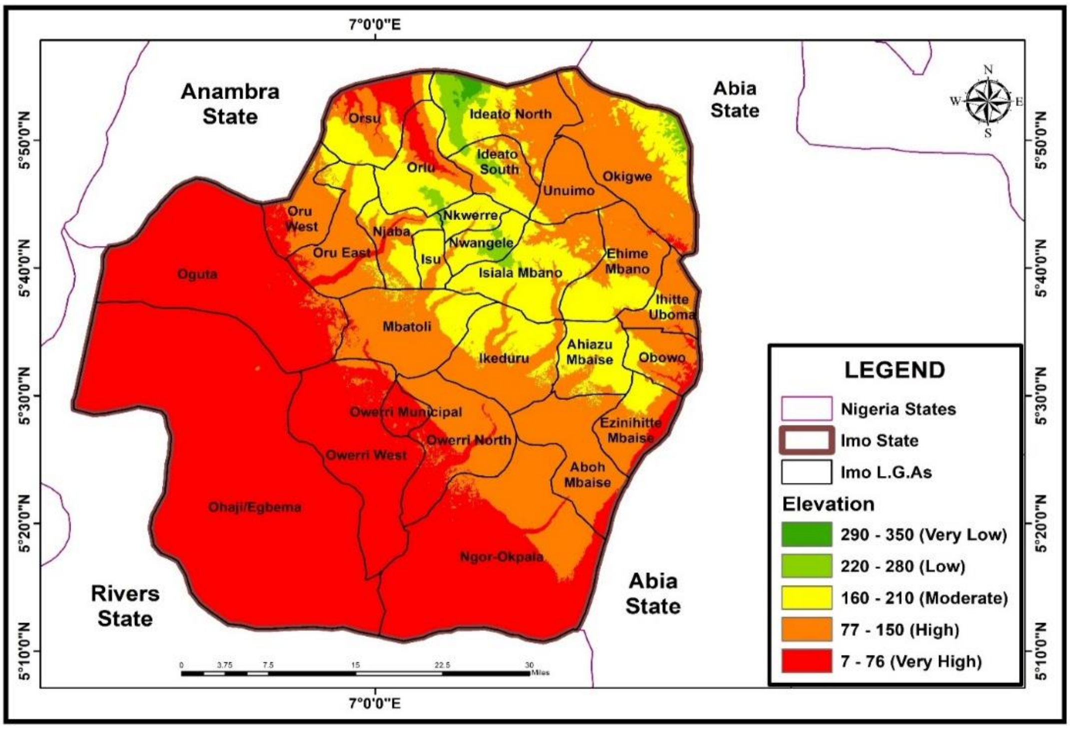

Figure 3: Elevation Map of Imo State
Source: Researcher's Compilation from GIS Lab – University of Uyo 2025

Figure 3 maps elevation as a key physical hazard component for Imo State, with five risk levels. Very high risk shown in bright red covers the lowest elevations from 7 to 76 meters. These zones cluster in western and southern local government areas such as Oguta, Oru West, Ohaji Egbema, Owerri West, Owerri Municipal, and Ngor Okpala. Low lying land here faces two problems. First, the ground saturates quickly during rain, reducing its ability to absorb water and increasing runoff. Second, these areas sit near major rivers, making them vulnerable to flooding and backwater effects that worsen sheet and rill erosion. In contrast, very low risk shown in bright green covers higher elevations from 290 to 350 meters, concentrated in northeastern local government areas like Okigwe, Unuimo, Ideato North and South, and Nwangele. While these places are highest above sea level, their slopes may be gentler or their soils more porous, lowering their overall erosion risk in this specific elevation model.

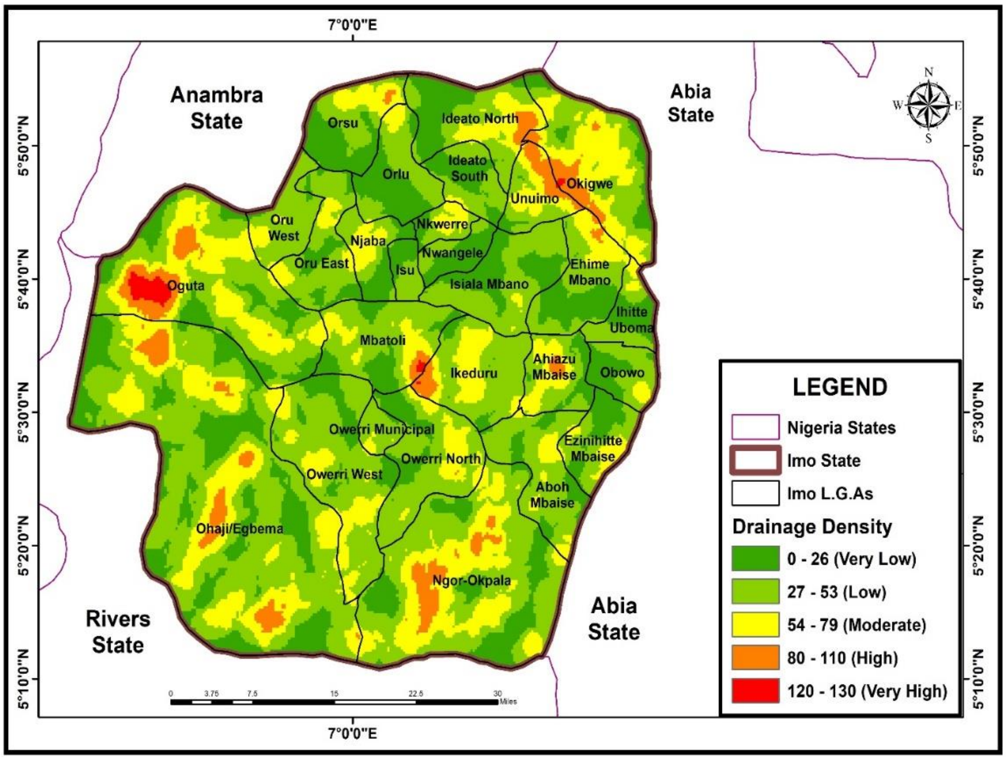

Figure 4: Drainage Density Map of Imo State
Source: Researcher's Compilation from GIS Lab – University of Uyo 2025

Figure 4 maps Drainage Density in Imo State, which measures the total length of stream channels per unit area. A high drainage density, shown in red and orange, means rainwater concentrates and moves away quickly, leaving little time for the ground to absorb it. This fast-moving water carries more energy to detach and transport soil, making erosion much more likely. The map reveals that the highest erosion risk zones are concentrated in the western and northwestern local government areas, especially Oguta and Oru West, where drainage density is very high. These sectors require urgent attention because physical hazard intersects with population and infrastructure. In contrast, the central local government areas show low to moderate drainage density and are less prone to erosion. This map helps the study zone the area effectively, ensuring that conservation and mitigation policies target the places facing the greatest inherent risk. Table 4.4 confirms that higher drainage density means more rapid runoff and concentrated stream power.

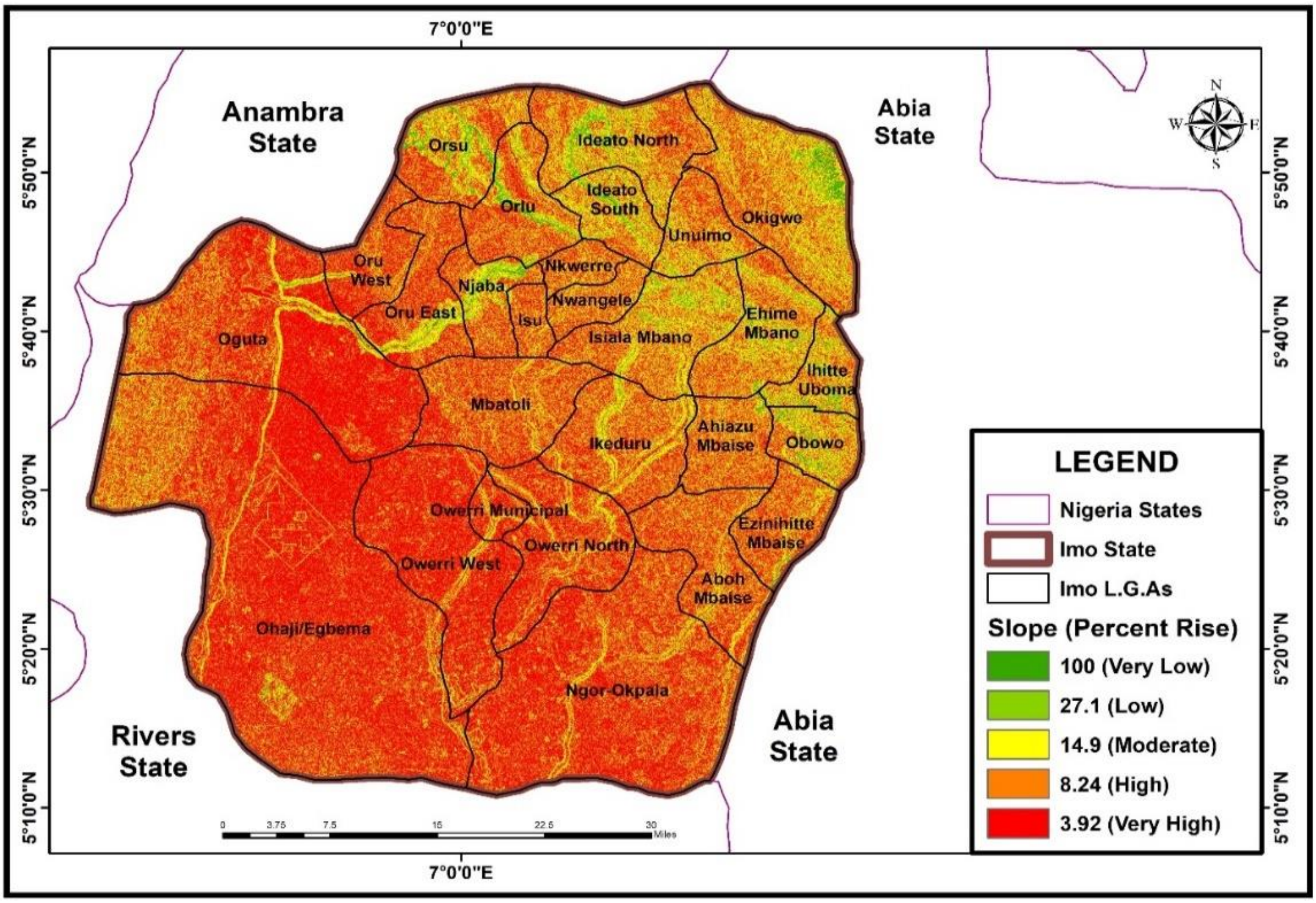

Figure 5: Slope Map of Imo State
Source: Researcher's Compilation from GIS Lab – University of Uyo 2025

The Slope map shows that most of Imo State falls into Very High- and High-Risk areas, with slopes between 3.92 and 8.24 degrees shown in red and orange. This confirms the terrain is generally flat to gently rolling. Erosion here is driven by poor drainage, water saturation, and human activity, not steep hills. The western and southern parts of the state including Ohaji Egbema, Oguta, Oru West, Owerri Municipal, and Ngor Okpala show the highest risk. These very gentle slopes are prone to ponding water and gully formation where drainage fails. Low and Very Low Risk zones with the steepest slopes from 27 to 100 degrees are concentrated in the northeastern local government areas like Ideato North, Orsu, and northern Okigwe. This map challenges the simple idea that steep slopes always mean high risk. Instead, it reveals a more complex truth where gentle terrain combined with poor drainage creates serious erosion danger.

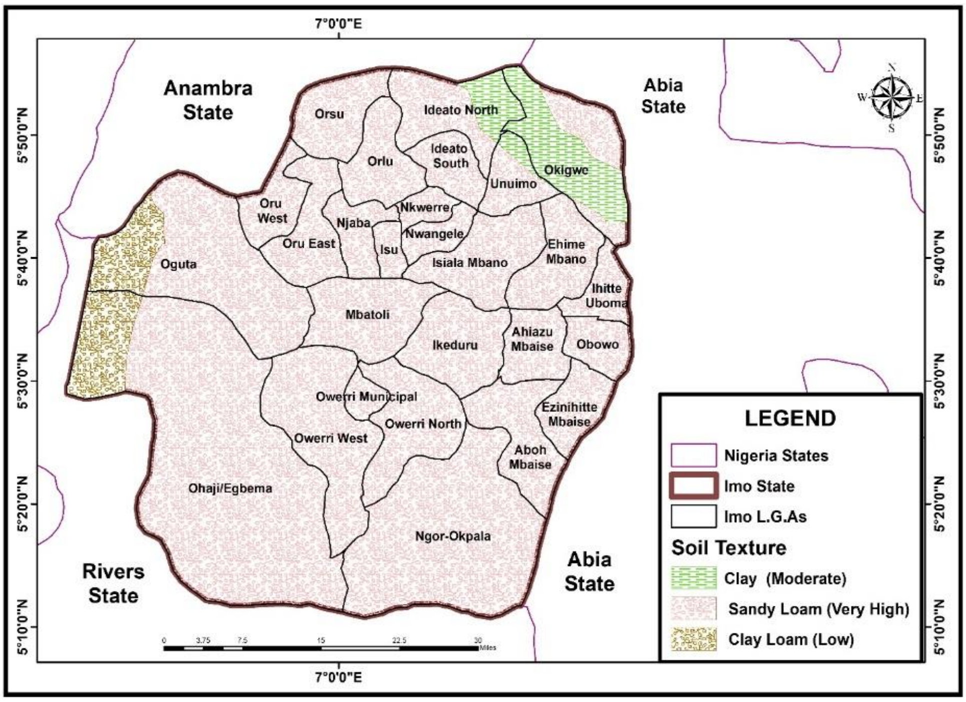

Figure 6: Soil Texture Map of Imo State
Source: FAO Compiled from GIS Lab – University of Uyo 2025

Figure 6 reveals a simple but powerful pattern. The vast majority of Imo State, including the central, western, and southern local government areas like Owerri, Mbaitoli, Ohaji Egbema, and Ngor Okpala, is covered by Sandy Loam, which carries Very High Risk. This means the soil itself is the single greatest and most widespread factor driving erosion across the state. Sandy Loam detaches and washes away easily whenever rain falls or land use changes. The lowest risk zone, shown in light green, is confined to the northeastern corner covering much of Okigwe and nearby areas. Here, Clay Loam offers more stability and structural strength. A Moderate Risk zone with Clay soil appears on the western edge in Oguta, where clay resists particle detachment, though runoff remains a concern. This map is critical because the widespread presence of highly erodible Sandy Loam confirms the foundational physical vulnerability that makes erosion worse with every heavy rainfall or disturbance of the land.

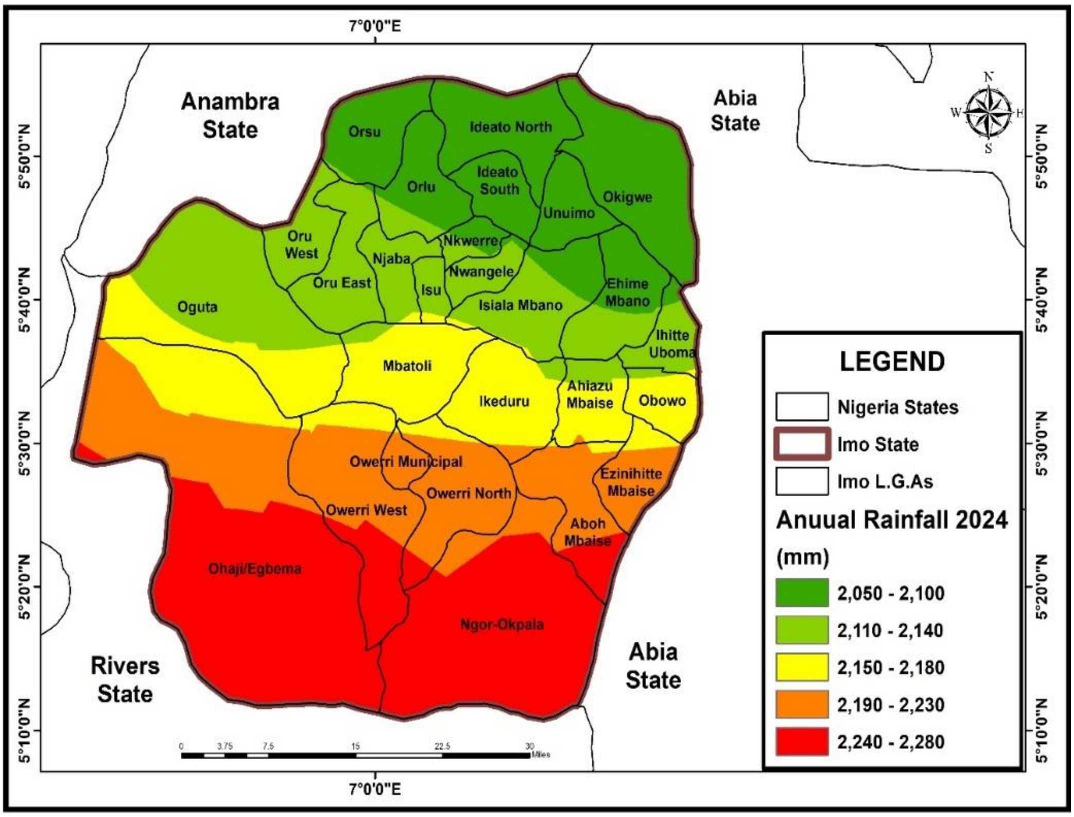

Figure 7: Mean Annual Rainfall Map of Imo State for 2024
Source: FAO Compiled from GIS Lab – University of Uyo 2025

Figure 7 maps yearly rainfall across Imo State, a key factor in understanding erosion risk. The visual pattern is clear. Precipitation is significantly higher in the southern regions, where "High" and "Very High" zones indicate extreme runoff potential. These areas face severe soil loss and deep gully formation. In contrast, the northern boundary receives lower annual rainfall. While the immediate risk of fast-moving runoff is reduced there, threats remain from wind erosion or localized water erosion, especially where poor land management meets vulnerable soils. For sustainable development, this map helps planners prioritize soil conservation measures, target engineering controls, and enforce smart land use policies where rain falls hardest. The table accompanying the figure details five classes, each linking rainfall quantity to predicted erosion severity. Understanding where water hits hardest is the first step toward protecting the land and the people who depend on it.

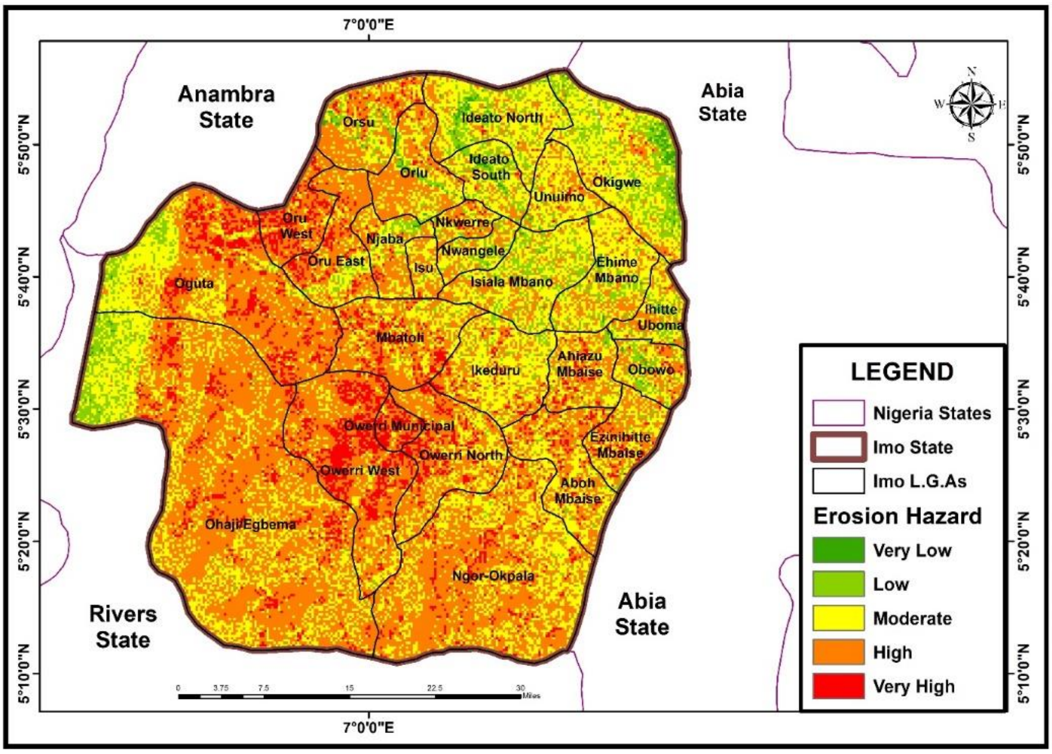

Figure 8: Erosion Hazard Map from Multi-Criteria Evaluation
Source: Researcher's Compilation from GIS Lab – University of Uyo 2025

The Erosion Risk Map in Figure 8 is the output of a Geographic Information System (GIS) multi-criteria evaluation (MCE), synthesizing complex environmental and physical data into a clear hazard assessment. This map is not merely a composite image but a weighted spatial model designed to prioritize intervention efforts across Imo State, Nigeria. The process involved classifying and scoring several key factors and then combining them using specific weights, reflecting their relative contribution to the erosion process in the region. The core of this analysis is the overlay function, where five distinct data layers were given specific influence percentages (weights) to determine the final risk score for every location on the map. This method acknowledges that not all factors contribute equally to the severity of the hazard.

Figure 9: Erosion Hazard Locations at Oru West - Imo State
Source: Researcher's Compilation from GIS Lab – University of Uyo 2025

Figure 10: Erosion Spots in Nekede Owerri
Source: Field Study, 2025

Figure 11: Erosion Spot Along Port Harcourt Road Owerri
Source: Field Study, 2025

The community interviews reveal gully erosion as a profound crisis in Imo State. The damage begins with land and infrastructure loss, then spreads to agriculture, livelihoods, mental health, and the collapse of local efforts. This pattern appears across nine communities, signaling a systemic regional disaster. Physical damage goes beyond losing soil. In Nekede, perimeter walls hang over voids. In Ihiagwa, foundational cracks threaten homes. This matches Igbokwe *et al*. (2018), who found that Imo Shale and unconsolidated sands are highly susceptible to gullies, especially when triggered by road building and poor drainage. Infrastructure destruction is catastrophic. Major roads like the Aboh Mbaise–Owerri Road are severed. Bridges are destroyed in Obokwe. Nwankwoala and Igbokwe (2019) confirm that gully erosion drives infrastructural collapse, crippling connectivity and trade.

The agricultural impact is devastating. Farmers report losing between half an acre and four acres of fertile land per family. Productivity has dropped over 60 percent in places like Isunjaba. Ofomata (1985) quantified annual arable land loss in thousands of hectares, pushing farming communities into poverty and menial labor, a shift explicitly mentioned in Amucha and Awo Omamma. The psychological toll is perhaps the most painful finding. The rainy season becomes a time of siege. Residents fear walls collapsing in Nekede, sudden ground subsidence in Awo Omamma, and lethal mudslides in Isunjaba. Amangabara *et al*. (2017) call this "erosion induced trauma," a state of constant anxiety that damages mental health and community bonds.

Finally, local mitigation efforts universally fail. Sandbag barriers in Nekede and check dams in Avuvu are consistently overpowered by the forces of water. This supports Agan (2019), who argues that gully erosion requires large scale engineered solutions, proper hydrological surveys, reinforced structures, and integrated watershed management. Community exhaustion is real. The problem has far exceeded local capacity. In short, gully erosion in Imo State is a multidimensional disaster. It is a geotechnical failure, a livelihoods catastrophe, an infrastructure emergency, and a human security crisis. The consistency between field reports and academic research demands urgent, coordinated, and well-funded action.

5. Conclusion and Policy Recommendations

The comprehensive multi-criteria evaluation (MCE) and community assessment achieved all core objectives, demonstrating that the gully erosion crisis in Imo State is a highly localized, socio-environmentally driven disaster requiring spatially differentiated policy interventions. The analysis concludes that erosion hazard is rooted in the pervasive, highly erodible Sandy Loam substrate. This inherent geological weakness is intensely exacerbated by two factors: Land Use/Land Cover (LULC) change (maximizing runoff velocity) and adverse hydro-geomorphology. The study revealed the counter-intuitive finding that gentle slopes in lowland areas are Very High Risk due to prolonged saturation, overriding the traditional risk-gradient model.

The MCE definitively identified the Owerri Metropolitan region as the Very High erosion vulnerability hotspot. This is driven by the catastrophic overlap of maximum Exposure (high Population Density) and critically low Adaptive Capacity (low HDI). This conclusion provides an indispensable framework for resource allocation, prioritizing structural defenses in this core hotspot to protect the maximum concentration of lives and assets.

The following recommendations were made;

(i) Prioritize immediate structural controls and drainage master planning in the Very High-Risk zones, especially the central urban corridor and western lowlands, to stabilize the highly erodible sandy loam substrate under intense anthropogenic pressure.

(ii) Implement focused capacity-building programs in the central-western high-vulnerability cluster to improve HDI scores and enforce strict land-use regulations that curb unplanned urban sprawl, thereby reducing exposure and enhancing adaptive capacity.

(iii) Adopt a spatially targeted intervention policy guided by the final risk map, mandating high-cost engineering works in Very High-Risk urban areas while promoting community-based conservation in high-hazard, high-HDI zones.

(iv) Launch an integrated state-wide disaster response and rehabilitation fund specifically for erosion, providing emergency aid for displaced households and subsidizing large-scale, engineered solutions to replace failed local mitigation attempts.

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