Geological Characterization and Soil Erodibility Factors in Parts of Southeastern, Nigeria

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Abstract
This study focuses on analyzing soil erodibility in five Local Government Areas (LGAs) in Imo State, Nigeria: Isu, Mbaitoli, Njaba, Orlu, and Oru East. These areas are prone to flooding due to their location within the lower Niger River Basin, exacerbating soil erosion. The study aims to evaluate geological and soil characteristics influencing landslide susceptibility in these LGAs. The aim of this study is to assess soil erodibility factors and geological characteristics in Imo State, Nigeria, focusing on Isu, Mbaitoli, Njaba, Orlu, and Oru East LGAs. It involves identifying predominant soil types, calculating Soil Erodibility Factor (K), and mapping erosion susceptibilities. The study correlates data with hydrological and climatic information to analyze landslide risks and propose mitigation strategies. This study utilizes data primarily from the Soil Map of the World, version 3.6, corrected for errors and updated for relevance. Geographic Information System (GIS) tools are employed for spatial analyses, including mapping soil types and erosion susceptibilities. The study also integrates topographical data to understand elevation variations and geological formations impacting soil characteristics. The study identifies two primary soil types: Dystric Nitosols covering 578.63 km² and Xanthic Ferralsols covering 0.064 km². Dystric Nitosols have a low Soil Erodibility Factor (K) of 0.017769 t.ha.h.ha/MJ/mm, indicating good structural stability and less susceptibility to erosion. In contrast, Xanthic Ferralsols exhibit a higher K-factor of 0.018724 t.ha.h.ha/MJ/mm, suggesting greater vulnerability to erosion due to their acidic nature and lower fertility. The spatial distribution of soil types and their erodibility factors highlights significant implications for agricultural productivity and environmental conservation. Dystric Nitosols, with their high fertility and good structure, support diverse crops and ecosystems. Effective management practices such as crop rotation and cover cropping are essential for sustaining their productivity. In contrast, Xanthic Ferralsols require intensive management to mitigate erosion risks and improve soil fertility through techniques like contour plowing and organic amendments. This study's comprehensive analysis of soil erodibility, topography, and geological characteristics provides insights crucial for sustainable land management and agricultural planning in Imo State, Nigeria. Implementing tailored soil conservation strategies is essential to maintain soil health, enhance agricultural productivity, and support ecological balance in the region. The novelty of this study lies in its detailed assessment of soil erodibility factors across distinct geological formations in Imo State, Nigeria. By integrating GIS analyses with empirical data, the study offers precise recommendations for mitigating landslide risks and preserving soil integrity amidst challenging environmental conditions.

Keywords: *Flood vulnerability, Imo State, Landslide susceptibility, Soil erodibility, Soil types*

1. Introduction

Soil erosion is one of the most pressing environmental challenges faced by many regions around the world. It is a process where the topsoil, which is rich in nutrients and organic matter, is worn away by natural forces such as water, wind, and ice, as well as human activities (Ahmad et al., 2020). This loss of topsoil can have severe repercussions on agricultural productivity, water quality, and overall ecosystem health.

The topsoil layer is vital for plant growth because it contains the majority of the soil's organic matter and nutrients. When this layer is eroded, the remaining soil may lack sufficient nutrients, making it difficult for crops to thrive (Guo et al., 2021). This can lead to reduced agricultural yields, affecting food security and the livelihoods of farmers. In many developing regions, including parts of Nigeria, where agriculture forms the backbone of the economy, the impact of soil erosion on crop production can be particularly devastating (Wynants et al., 2021). Farmers in these areas often rely on the same land for multiple growing seasons, making the preservation of soil health critical for sustainable agriculture (Ahmad et al., 2020; Ayadiuno et al., 2021). Without the protective cover of vegetation or the rich organic content of topsoil, the land becomes less fertile over time, and farmers may need to invest in expensive fertilizers and soil amendments to maintain productivity, which can be economically unfeasible for many.

As soil particles are carried away by runoff, they often enter water bodies such as rivers, lakes, and reservoirs. This sedimentation can reduce the water quality by increasing turbidity, which impacts aquatic life and ecosystems (Abbasi et al., 2022). Increased turbidity reduces the amount of sunlight that penetrates the water, which can affect the growth of aquatic plants and the overall health of the aquatic ecosystem (Touma et al., 2020; Wang et al., 2021). Eroded soil can carry with it pesticides, fertilizers, and other pollutants that further degrade water quality. This pollution can have downstream effects, harming fisheries, reducing biodiversity, and affecting the quality of water available for human consumption and recreational activities (Rehm et al., 2021).

The loss of nutrient-rich topsoil can lead to the degradation of habitats, affecting plant and animal species that depend on healthy soil for food and shelter. Erosion can also lead to the formation of gullies and other landforms that can alter the landscape, changing drainage patterns and further impacting ecosystems (Seabloom et al., 2021). In severe cases, land that has been heavily eroded may become barren and unproductive, leading to desertification. Desertification is a particularly severe form of land degradation where fertile land becomes desert, typically as a result of drought, deforestation, or inappropriate agriculture (Azare et al., 2020). This process not only reduces the land's productivity but also contributes to the displacement of human populations and the loss of biodiversity.

Given these widespread impacts, understanding soil erodibility, or the susceptibility of soil to erosion, is essential for effective land management and conservation strategies. Soil erodibility is influenced by several factors, including soil texture, structure, organic matter content, and permeability. Soil texture refers to the proportion of sand, silt, and clay particles, with each type having different susceptibility to erosion (Songu et al., 2021; Luo et al., 2022). Sandy soils are more prone to wind erosion, while clayey soils might be more resistant to water erosion due to their cohesiveness. Organic matter content enhances soil structure and porosity, making the soil more resistant to erosion. By assessing these factors, land managers can identify areas at high risk of erosion and implement measures to protect and restore vulnerable soils (Nebeokike et al., 2020; Amah et al., 2020). Such measures may include planting cover crops, practicing no-till farming, constructing terraces, and creating buffer strips along waterways to reduce runoff and sedimentation.

Moreover, technological advances such as geographic information systems (GIS) and remote sensing can aid in monitoring and managing soil erosion. These tools allow for the mapping of erosion-prone areas, the assessment of erosion rates, and the evaluation of the effectiveness of soil conservation practices (Achasov et al., 2021). Public awareness and education about the importance of soil conservation can also play a crucial role in mitigating soil erosion. Engaging local communities in sustainable land management practices and promoting policies that support soil health can contribute to long-term environmental sustainability (Ukabiala et al., 2021).

Addressing soil erosion requires a multifaceted approach that combines scientific knowledge, technological innovation, community involvement, and policy support. By understanding the factors that contribute to soil erodibility and implementing effective conservation strategies, it is possible to mitigate the adverse effects of soil erosion and protect the vital topsoil that sustains agricultural productivity, water quality, and ecosystem health (Nebeokike et al., 2020; Amah et al., 2021).

This study focuses on analyzing soil erodibility in five Local Government Areas (LGAs) in Imo State, Nigeria: Isu, Mbaitoli, Njaba, Orlu, and Oru East. These areas are particularly vulnerable to flooding due to their location within the lower Niger River Basin. The basin's topography, soil types, and climatic conditions contribute to frequent and severe flooding events, which exacerbate soil erosion. This study aims to evaluate the geological and soil characteristics that influence landslide susceptibility in Imo State, Nigeria, focusing on Isu, Mbaitoli, Njaba, Orlu, and Oru East LGAs. It involves identifying and characterizing predominant soil types, calculating the Soil Erodibility Factor (K) using empirical formulas, and mapping areas with varying erosion susceptibilities. By correlating soil erodibility data with hydrological and climatic information, the study will analyze landslide risks and provide recommendations for soil conservation and landslide mitigation tailored to the specific conditions of the study area.

2. Research Location and Geology

Isu, Mbaitoli, Njaba, Orlu, and Oru East are Local Government Areas (LGAs) situated in Imo State, Southeastern Nigeria. These LGAs form a contiguous region characterized by a blend of urban and rural settlements. Imo State is located between latitudes 4°45'N and 7°15'N and longitudes 6°50'E and 7°25'E. The specific coordinates for the central points of these LGAs are approximately 5.6650° N, 7.1074° E for Isu, 5.6058° N, 7.0200° E for Mbaitoli, 5.7493° N, 7.0255° E for Njaba, 5.7850° N, 7.0339° E for Orlu, and 5.7917° N, 6.9822° E for Oru East as shown in Figure 1. These coordinates provide a rough central point for the LGAs, which cover diverse terrains and communities.

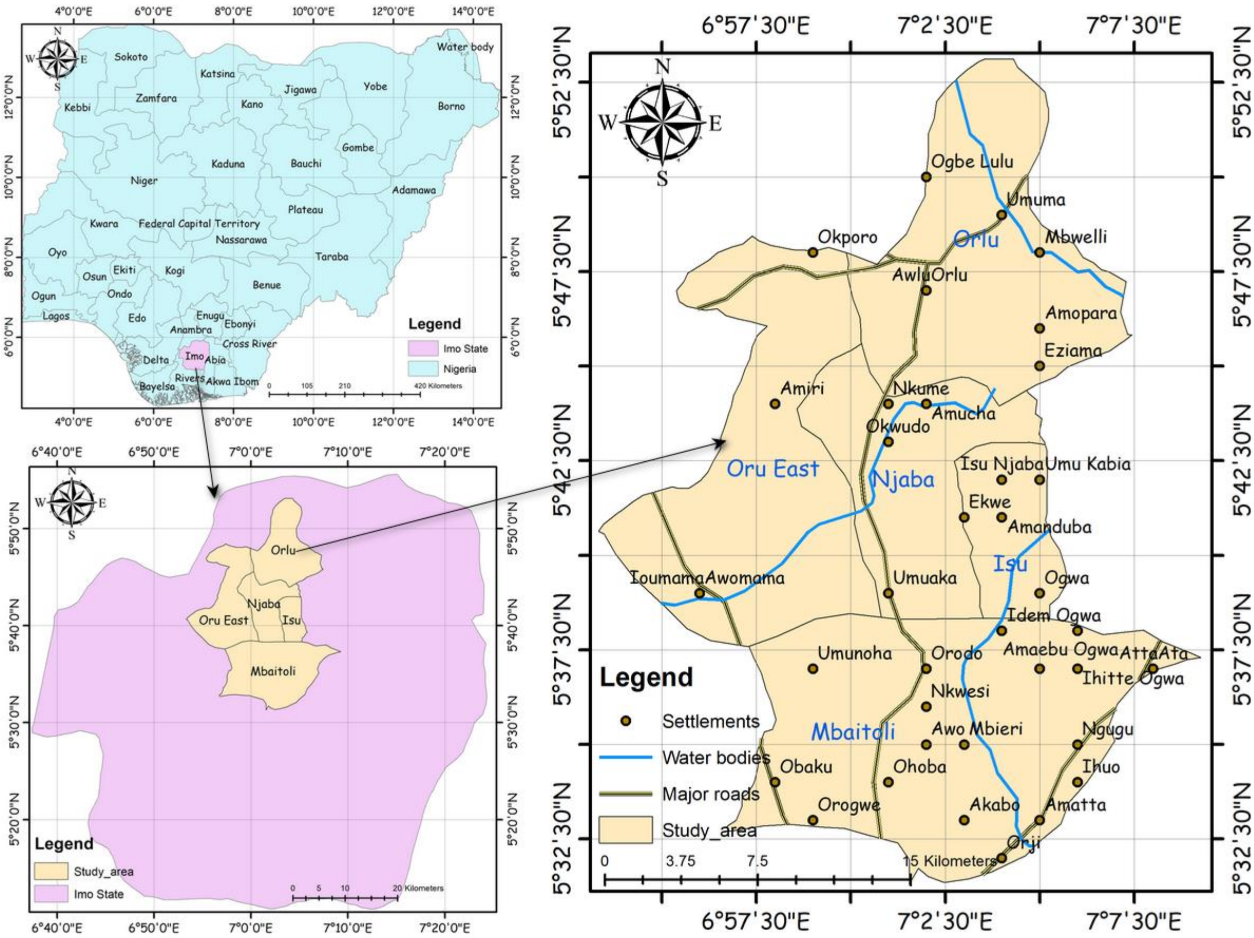

Figure 1: Map of Nigeria, Imo, and the study area

The drainage system in this region is influenced by its topography and climate. The area is characterized by a network of rivers and streams, which form part of the larger Niger River Basin. Key rivers in the region include the Njaba River, Orashi River, and their tributaries. These rivers play a crucial role in the hydrology of the area, providing water for agriculture, domestic use, and supporting local ecosystems. The drainage pattern is primarily dendritic, indicative of the underlying geology and terrain.

Flooding is a common issue in these LGAs, especially during the rainy season, due to the heavy rainfall and poor drainage infrastructure. This often exacerbates soil erosion and impacts agricultural activities. Efforts to improve drainage systems are ongoing, but challenges remain due to the complex interaction between natural and human factors. The frequent flooding events not only erode the soil but also deposit sediments in unwanted areas, which further complicates land management and agricultural practices. Effective drainage systems are crucial in mitigating these impacts and ensuring the sustainability of local agriculture and habitats.

The road network within Isu, Mbaitoli, Njaba, Orlu, and Oru East LGAs is a mix of tarred and untarred roads. Major highways and roads such as the Owerri-Orlu Road and the Onitsha-Owerri Expressway facilitate connectivity within and outside these LGAs. However, many of the rural roads are in poor condition, especially during the rainy season, which hampers transportation and economic activities (Okoli et al., 2024). The condition of the roads significantly affects the mobility of people and goods, impacting local economies and access to essential services. Poor road conditions can lead to increased travel times, higher vehicle maintenance costs, and limited access to markets for agricultural produce. Improving the road infrastructure is critical for the socio-economic development of the region, enhancing access to markets, healthcare, education, and other essential services. Good road networks also play a vital role in emergency response and disaster management, particularly in mitigating the impacts of flooding and erosion.

The geology of Isu, Mbaitoli, Njaba, Orlu, and Oru East LGAs is predominantly characterized by three major geological formations: the Benin Formation, the Ogwashi-Asaba Formation, and the Ameki Group. The Benin Formation, dating from the Oligocene to recent periods, is composed mainly of unconsolidated sands, gravel, and clay. This formation is known for its high permeability and serves as an important aquifer for groundwater (Okoli et al., 2024). The sandy nature of this formation makes it susceptible to erosion, especially in areas with little vegetation cover. This susceptibility to erosion is a significant concern for land management in the region, as the loss of topsoil can reduce agricultural productivity and increase the need for soil conservation measures.

The Ogwashi-Asaba Formation consists of alternating sequences of lignite, sandstones, and clays. This Eocene formation is significant for its coal deposits, which have been historically mined in the region. The alternating layers of sandstones and clays influence the area's drainage characteristics and contribute to the formation of ridges and valleys. These geological features affect the distribution of soil types and their susceptibility to erosion, with certain areas being more prone to landslides and gully formation (Okoli et al., 2024). Understanding the geological characteristics of the Ogwashi-Asaba Formation is crucial for developing effective land use and management strategies to mitigate the impacts of erosion and support sustainable development.

The Ameki Group, also of Eocene age, is characterized by sandstones, shales, and limestone. This group is known for its fossiliferous content and contributes to the understanding of the region's paleoenvironments. The geological characteristics of the Ameki Group, with its mix of lithologies, affect soil fertility and stability. Areas underlain by the Ameki Group are often more resistant to erosion due to the cohesive nature of the shales and the protective cover provided by limestone outcrops (Okoli et al., 2024). However, the presence of sandstones can also make certain areas vulnerable to erosion if not properly managed. The diverse geological characteristics of the Ameki Group present both opportunities and challenges for land management in the region.

3. Materials and Methods

3.1 Data Sources and Preparation

This study utilized multiple datasets to conduct comprehensive analyses and modeling tasks. One of the primary sources of soil type data was the digitized Soil Map of the World, version 3.6. Initially published between 1974 and 1978 and subsequently updated to January 1994, this map was produced by the Food and Agriculture Organization (FAO). It offers a comprehensive global representation of soil types at a 1:5,000,000 scale. To ensure accuracy, the dataset was meticulously corrected for database and digitized map errors (Adewumi et al., 2023).

To accommodate different geographic regions, the Americas utilized a bipolar oblique conformal projection, while other regions employed the Miller oblated stereographic projection. The updated map series included intersections with water-related features and revised country boundaries, enhancing the dataset's relevance for contemporary studies (Akaolisa et al., 2023). The digital database was maintained in a Geographic projection, ensuring global compatibility and ease of integration with other spatial data.

3.2 Soil Erodibility Factor (K)

The Soil Erodibility Factor (K) is a crucial component in understanding soil erosion processes. It represents the susceptibility of soils to erosion, influenced by several soil properties, including texture, organic matter content, structure, and permeability (Amah et al., 2020; Yang et al., 2021). To calculate the K Factor, key soil properties such as the percentages of sand, silt, and clay, along with organic matter content and soil structure, were analyzed. Soils with high permeability, high organic matter content, and good structure tend to resist erosion better than those with high silt content (Yu et al., 2020). These properties were systematically measured and integrated into established empirical formulas to determine the K Factor.

The K Factor was calculated using William's equation, which incorporates the following parameters:

$$K_{factor} = f_{sand} \times f_{clays} \times f_{orgc} \times f_{silt} \times 0.1317$$

1

$$f_{sand} = \left(0.2 + 0.3exp\left[-0.256 \times M_{sand} \times \left(1 - \frac{M_{silt}}{100}\right)\right]\right)$$

2

$$f_{clay} = \left(\frac{M_{silt}}{M_{clay}+M_{silt}}\right)^{0.3}$$

3

$$f_{orgc} = \left(1 - \frac{0.0256orgc}{orgc+exp[3.72-2.95orgc]}\right)$$

4

$$f_{silt} = \left(1 - \frac{0.7\left(1-\frac{M_{sand}}{100}\right)}{\left(1-\frac{M_{sand}}{100}\right)+exp\left[-5.51+22.9\left(1-\frac{M_{sand}}{100}\right)\right]}\right)$$

5

By applying this equation, a comprehensive K Factor map was generated. This map highlights areas with varying levels of erosion susceptibility, serving as a valuable tool for soil conservation planning.

3.3 Data Analysis and Modeling

The datasets were instrumental in various analyses and modeling tasks conducted in the study, providing a robust foundation for evaluating land use patterns and soil characteristics. The digitized Soil Map of the World, version 3.6, was crucial in identifying soil types across the study region (Riza et al., 2021). The map's global scale and detailed representation allowed for precise analysis of soil properties and their impact on erosion.

By integrating the soil type data with other spatial datasets, such as topography, land use, and climatic variables, a comprehensive model of soil erosion susceptibility was developed. The K Factor map was a key output of this modeling effort, providing detailed insights into the spatial distribution of soil erodibility (Zweifel et al., 2021). This map is instrumental in identifying regions prone to erosion, allowing for targeted soil conservation measures. By understanding the spatial distribution of soil erodibility, land managers and planners can develop effective strategies to mitigate erosion risks (Rosskopf et al., 2020; Alaboz et al., 2021). This approach supports sustainable land management practices and the preservation of soil resources.

4. Result and Discussion

4.1 Topographical Analysis and Elevation Variations in the Study Area

The elevation map of the study area, depicted in Figure 2, illustrates a range of elevations from 22 to 242 meters. This variability in elevation is critical for understanding the geographical and topographical nuances of the region. The water bodies in the northern and western parts of the study area exhibit lower elevations, typically between 22 to 38 meters. This relatively low elevation is indicative of the flat terrain commonly associated with such bodies of water, facilitating drainage and potentially impacting local ecosystems and human activities.

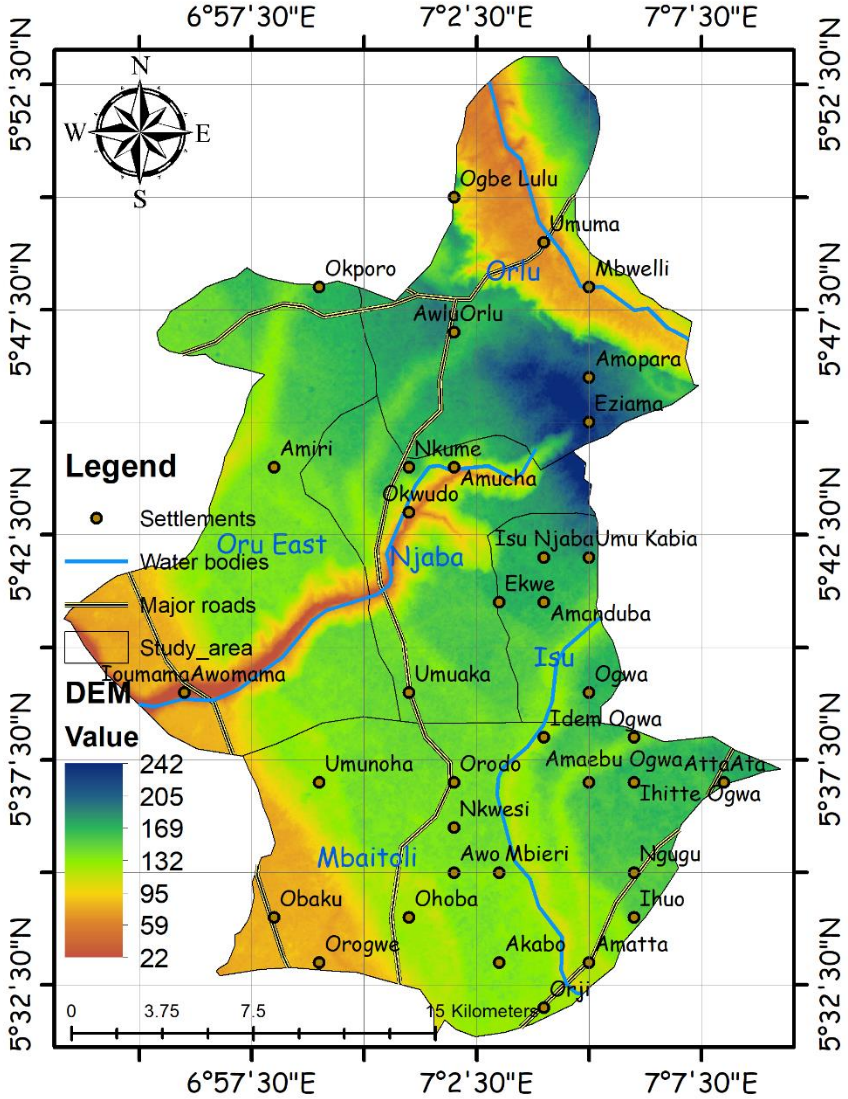

Figure 2: Elevation Map of the Study Area Showing Topographical Variations

In contrast, the water body located in the southeastern part of the study area presents a higher elevation, ranging from approximately 45 to 78 meters. This elevation is notably higher than the other water bodies within the study area, suggesting the presence of elevated landforms or geological structures that influence the water body's position. The variation in elevation among water bodies could have significant implications for water flow, sediment transport, and the overall hydrology of the region.

The western central part of the study area is characterized by the highest elevations, reaching up to 242 meters. This area likely contains hills or small mountains, contributing to its elevated terrain. Such high elevations can affect weather patterns, vegetation types, and land use practices in the region. The presence of high ground in the western central part of the study area might also play a role in water runoff and soil erosion, impacting both natural and human systems.

Conversely, the tips of the southwestern part of the study area are marked by the lowest elevations, reinforcing the varied topography within the region. These lower elevations might be part of a broader valley or plain, which could influence local climate conditions, agricultural practices, and settlement patterns. The contrast between the highest and lowest points within the study area highlights the diverse landscape, which can support a range of biodiversity and offer different opportunities and challenges for land use and development.

Understanding these elevation differences is crucial for any environmental or developmental planning within the study area. The topographical variation can affect infrastructure development, agricultural productivity, and ecological conservation efforts. Therefore, the elevation map serves as a foundational tool for researchers, policymakers, and planners engaged in the study and sustainable management of the region.

4.2 Geological Units and Their Spatial Distribution

The study area encompasses three primary geological formations: the Benin Formation, the Ogwashi-Asaba Formation, and the Ameki Group as shown in. Figure 3.

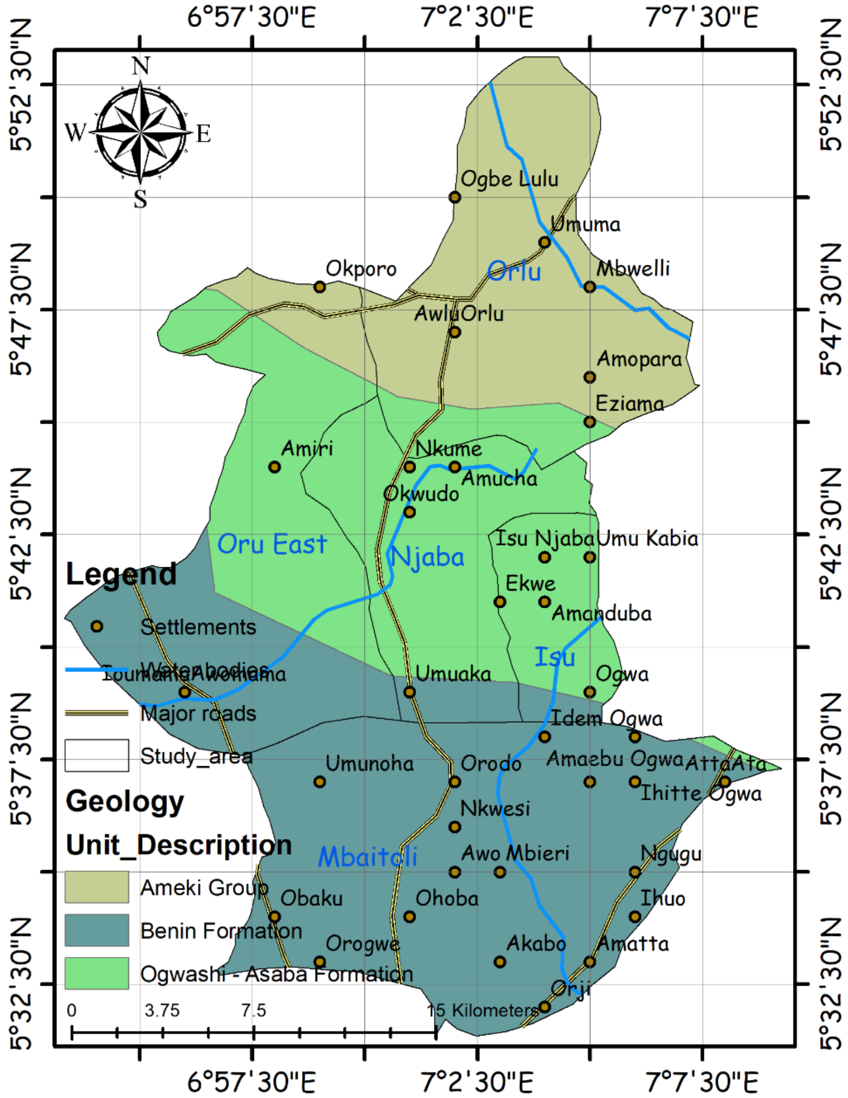

Figure 3: Spatial Distribution of Geological Formations in the Study Area

The Benin Formation is the most extensive geological unit in the study area, covering an area of 264.318013 km^2. This formation predominantly consists of coarse to medium-grained sands, interbedded with gravel and clay. The large area covered by the Benin Formation suggests it plays a significant role in the region's hydrogeology and land use patterns. Its sandy composition is likely to influence groundwater recharge and storage, making it an important aquifer. The extensive spread also implies that the Benin Formation is a crucial determinant of soil properties, affecting agricultural productivity and vegetation types across a substantial portion of the study area.

The Ogwashi-Asaba Formation, covering 186.303357 km^2, is the second-largest geological unit in the study area. This formation is characterized by alternating sequences of lignite, clay, and sand. The presence of lignite indicates potential coal resources, which could be economically significant. The alternating layers of clay and sand within the Ogwashi-Asaba Formation suggest variable permeability, impacting groundwater movement and storage. The clay layers can act as confining units, creating perched aquifers or influencing the direction and speed of groundwater flow. Understanding these properties is vital for managing water resources and assessing the feasibility of extracting any mineral resources within this formation.

The Ameki Group is the smallest geological unit in the study area, covering 128.073966 km^2. It is composed of sandstones, shales, and mudstones, which are indicative of a marine depositional environment. The variation in lithology within the Ameki Group suggests a complex geological history, including periods of marine transgression and regression. The presence of shales and mudstones indicates low permeability zones, which could act as barriers to groundwater flow. These characteristics are crucial for understanding the area's hydrogeological framework and for planning any subsurface exploration activities. Additionally, the diverse lithology of the Ameki Group can affect soil fertility and stability, influencing land use decisions.

The extensive area covered by the Benin Formation, with its high sand content, suggests a significant potential for groundwater storage and recharge. This formation's hydrogeological properties make it a vital water resource for the region, supporting both domestic and agricultural water needs. In contrast, the Ogwashi-Asaba Formation's alternating layers of clay and sand indicate more complex groundwater dynamics, with potential for both confined and unconfined aquifers. The Ameki Group, with its lower permeability shales and mudstones, may contribute less to groundwater storage but can influence surface water runoff and erosion patterns.

The presence of lignite in the Ogwashi-Asaba Formation highlights potential coal resources, which could be economically valuable. However, the feasibility of extracting these resources depends on several factors, including the depth and quality of the lignite seams, environmental considerations, and economic viability. The Ameki Group's diverse lithology, including sandstones, shales, and mudstones, suggests potential for other mineral resources, though further exploration would be required to assess their economic potential.

Understanding the spatial distribution of these geological units is essential for informed land use planning. The Benin Formation's extensive sandy areas may be well-suited for agriculture, given proper soil management practices to address potential issues such as erosion or nutrient leaching. The Ogwashi-Asaba Formation's clayey layers could pose challenges for construction due to their potential for swelling and shrinkage, but they might also provide suitable sites for specific agricultural practices or as sources of clay for industrial use. The Ameki Group's mixed lithology requires careful consideration in land use planning, particularly in terms of slope stability and soil fertility.

The different geological formations also have implications for the region's ecology. The Benin Formation's sandy soils may support specific types of vegetation adapted to well-drained conditions, while the Ogwashi-Asaba Formation's varied lithology can create diverse habitats. The Ameki Group's shales and mudstones can support unique ecological niches, contributing to the region's biodiversity. Understanding these ecological dynamics is crucial for conservation efforts and sustainable development planning.

4.3 Soil Types and Their Spatial Distribution

The study area comprises two distinct soil types: Dystric Nitosols and Xanthic Ferralsols. These soil types are illustrated in Figure 4, which highlights their spatial distribution and relative areas. Understanding the distribution and characteristics of these soils is crucial for agricultural planning, land use management, and ecological conservation.

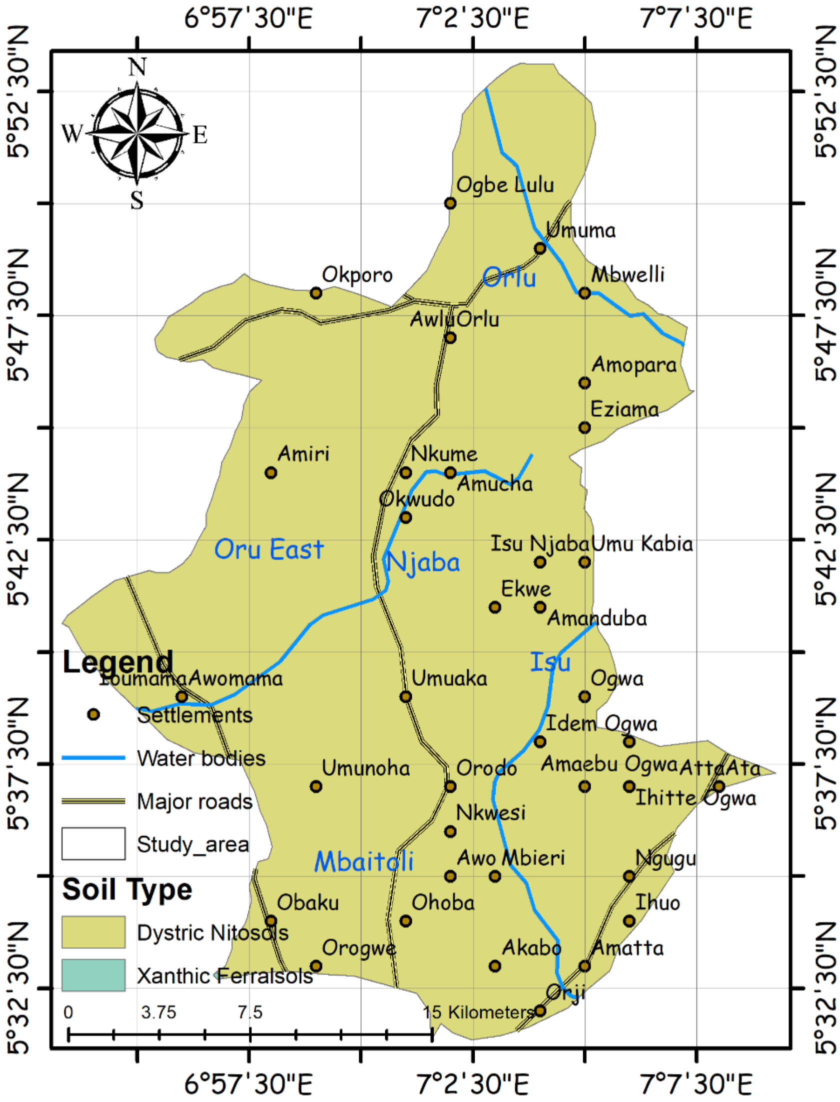

Figure 4: Spatial Distribution of Soil Types in the Study Area

Dystric Nitosols cover the vast majority of the study area, encompassing 578.630971 km^2 Nitosols are typically well-drained, deep soils found in humid tropical and subtropical regions.

They are known for their high fertility, particularly for their capacity to support a wide range of crops. The dominance of Dystric Nitosols in the study area suggests that the region is well-suited for agricultural activities, particularly for crops that require deep, well-aerated soils.

The high organic matter content in Dystric Nitosols contributes to their fertility, supporting the growth of both annual and perennial crops. These soils are also characterized by good structure and porosity, which enhance root penetration and water infiltration. Consequently, areas covered by Dystric Nitosols are likely to be highly productive, provided that other agronomic factors such as climate, crop selection, and farming practices are optimized.

The presence of Dystric Nitosols also has implications for water management. Their good drainage properties reduce the risk of waterlogging, which is beneficial for most crops. However, it also means that these soils may require careful management to maintain adequate moisture levels, particularly during dry periods. Irrigation systems and practices that promote water retention, such as mulching or cover cropping, could be essential in managing these soils effectively.

Xanthic Ferralsols cover a much smaller area of the study region, with only 0.064375 km^2. Ferralsols are highly weathered soils found in tropical regions with high rainfall. They are typically low in natural fertility due to the intense leaching of nutrients. The presence of Xanthic Ferralsols, albeit in a small area, indicates zones that may require specific management practices to enhance their productivity.

Xanthic Ferralsols are characterized by a high content of iron and aluminum oxides, which can lead to issues with soil acidity and nutrient availability. The acidic nature of these soils may require liming to adjust pH levels for optimal crop growth. Additionally, the low nutrient status of Ferralsols means that they often require substantial inputs of fertilizers and organic amendments to support agricultural activities.

Given the small area covered by Xanthic Ferralsols, their impact on the overall agricultural potential of the study area is limited. However, for landowners and farmers operating in these zones, understanding the specific challenges and requirements of managing Ferralsols is crucial. Techniques such as agroforestry, which integrates trees and shrubs into agricultural landscapes, can help improve soil fertility and structure over time.

The extensive coverage of Dystric Nitosols underlines the high agricultural potential of the study area. These soils are well-suited for a variety of crops, including cereals, legumes, root crops, and vegetables. Their good drainage and high fertility make them ideal for both subsistence and commercial farming. In contrast, the limited area of Xanthic Ferralsols suggests that these soils are less significant in terms of overall agricultural production. However, targeted management practices can enhance the productivity of Ferralsols, ensuring that even small areas contribute to the region's agricultural output.

Effective soil management practices are essential for maintaining and enhancing the productivity of both soil types. For Dystric Nitosols, practices that maintain soil structure and organic matter content, such as crop rotation, cover cropping, and reduced tillage, are beneficial. These practices help prevent soil erosion, enhance water retention, and promote healthy soil microbiota.

For Xanthic Ferralsols, more intensive management is required to address soil acidity and nutrient deficiencies. Liming to adjust soil pH, combined with the application of organic and inorganic fertilizers, can improve soil fertility. Additionally, incorporating organic matter through composting or green manuring can enhance soil structure and water-holding capacity.

The distribution of soil types also has implications for environmental and ecological conservation. Dystric Nitosols, with their high fertility and good structure, can support diverse plant communities and contribute to healthy ecosystems. Sustainable agricultural practices that maintain soil health can also support biodiversity and ecosystem services.

In contrast, Xanthic Ferralsols, with their poor fertility and susceptibility to erosion, require careful management to prevent land degradation. Conservation practices such as maintaining ground cover, avoiding overgrazing, and implementing erosion control measures are crucial for preserving these soils and the ecosystems they support.

4.4 Spatial distribution of Soil Erodibility

The study area includes two distinct soil types: Dystric Nitosols and Xanthic Ferralsols. Figure 5 illustrates their spatial distribution, area percentage, and soil erodibility factors.

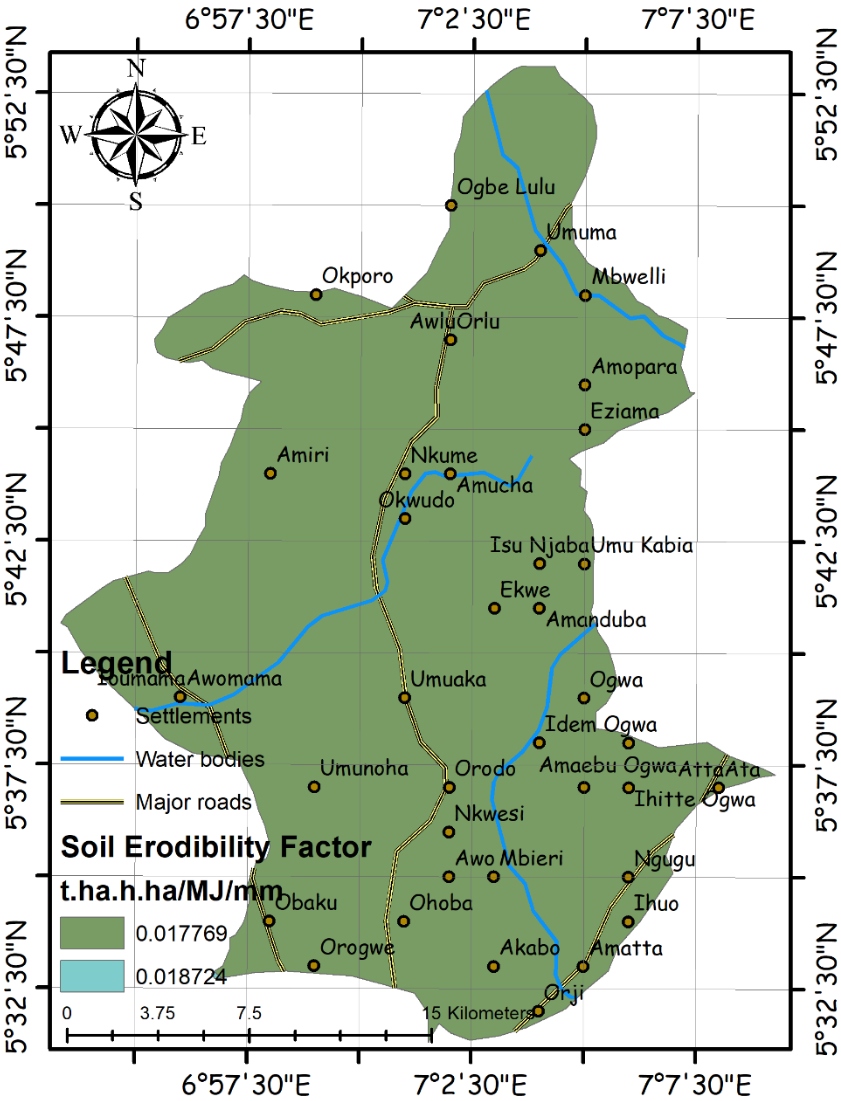

Figure 5: Spatial Distribution and Erodibility of Soil Types in the Study Area

The soil erodibility factor (K) for Dystric Nitosols is 0.017769 t.ha.h.ha/MJ/mm. This value reflects the soil's susceptibility to erosion by water. The relatively low K-factor indicates that Dystric Nitosols have good structural stability and are less prone to erosion compared to more erodible soils. Despite their low erodibility, sustainable management practices are essential to maintain soil health and prevent degradation. Practices such as crop rotation, cover cropping, and maintaining ground cover can help preserve soil structure and reduce erosion risks.

The low erodibility of Dystric Nitosols means they are generally more stable and capable of supporting various land uses without significant risk of soil loss. This stability is beneficial for long-term agricultural productivity, as it ensures that the soil can withstand erosive forces during heavy rainfall and other weather events. However, improper management can still lead to degradation over time. Therefore, implementing sustainable practices is crucial to maintain the soil's integrity, support crop growth, and preserve the ecological balance.

The soil erodibility factor for Xanthic Ferralsols is 0.018724 t.ha.h.ha/MJ/mm, slightly higher than that of Dystric Nitosols, indicating a greater susceptibility to erosion. The higher K-factor reflects the challenges associated with managing Ferralsols, particularly in terms of preventing soil erosion and maintaining soil fertility. Effective management practices for these soils include maintaining vegetation cover, using contour plowing, and applying organic amendments to improve soil structure and reduce erosion risks.

The higher erodibility of Xanthic Ferralsols implies that these soils are more vulnerable to the impacts of water erosion. This vulnerability necessitates more intensive management practices to prevent soil loss and degradation. Maintaining vegetation cover is particularly important as it protects the soil surface from direct raindrop impact and reduces runoff velocity. Contour plowing can help slow down water flow and encourage water infiltration, while organic amendments can enhance soil structure and increase its resistance to erosive forces.

5. Conclusion

This study focuses on analyzing soil erodibility in five Local Government Areas (LGAs) in Imo State, Nigeria: Isu, Mbaitoli, Njaba, Orlu, and Oru East. These areas are particularly vulnerable to flooding due to their location within the lower Niger River Basin. The basin's topography, soil types, and climatic conditions contribute to frequent and severe flooding events, exacerbating soil erosion. This study aimed to evaluate the geological and soil characteristics that influence landslide susceptibility in these LGAs. It involved identifying and characterizing predominant soil types, calculating the Soil Erodibility Factor (K) using empirical formulas, and mapping areas with varying erosion susceptibilities. By correlating soil erodibility data with hydrological and climatic information, the study analyzed landslide risks and provided recommendations for soil conservation and landslide mitigation tailored to the specific conditions of the study area.

The study area encompasses two primary soil types: Dystric Nitosols and Xanthic Ferralsols. Dystric Nitosols cover 578.63 km², representing 99.99% of the area, while Xanthic Ferralsols cover a mere 0.064 km², or 0.01% of the area. Dystric Nitosols have a Soil Erodibility Factor (K) of 0.017769 t.ha.h.ha/MJ/mm, indicating the soil's susceptibility to erosion by water. The relatively low K-factor suggests that Dystric Nitosols have good structural stability and are less prone to erosion compared to more erodible soils. The high organic matter content in Dystric Nitosols contributes to their fertility, supporting a variety of crops. These soils are characterized by good structure and porosity, enhancing root penetration and water infiltration. Despite their low erodibility, sustainable management practices are essential to maintain soil health and prevent degradation. Practices such as crop rotation, cover cropping, and maintaining ground cover can help preserve soil structure and reduce erosion risks.

In contrast, Xanthic Ferralsols have a Soil Erodibility Factor (K) of 0.018724 t.ha.h.ha/MJ/mm, which is slightly higher than that of Dystric Nitosols, indicating a greater susceptibility to erosion. This higher K-factor reflects the challenges associated with managing Ferralsols, particularly in terms of preventing soil erosion and maintaining soil fertility. Xanthic Ferralsols are characterized by a high content of iron and aluminum oxides, which can lead to soil acidity and nutrient availability issues. The acidic nature of these soils may require liming to adjust pH levels for optimal crop growth. Effective management practices for these soils include maintaining vegetation cover, using contour plowing, and applying organic amendments to improve soil structure and reduce erosion risks. The higher erodibility of Xanthic Ferralsols implies that these soils are more vulnerable to the impacts of water erosion. This vulnerability necessitates more intensive management practices to prevent soil loss and degradation.

The elevation map of the study area illustrates a range of elevations from 22 to 242 meters, highlighting the region's topographical variations. Low elevation areas, between 22 and 38 meters, are predominantly found in the northern and western parts of the study area. These regions exhibit flat terrain associated with water bodies, impacting local ecosystems and human activities. Higher elevation areas, ranging from 45 to 78 meters, are located in the southeastern part of the study area. This suggests the presence of elevated landforms or geological structures influencing the position of water bodies. The western central part of the study area is characterized by the highest elevations, reaching up to 242 meters. This area likely contains hills or small mountains, contributing to its elevated terrain. Conversely, the tips of the southwestern part of the study area are marked by the lowest elevations, indicative of valleys or plains, which can influence local climate conditions, agricultural practices, and settlement patterns.

The soil erodibility factors highlight the need for tailored management practices to maintain soil health and support sustainable land use. The extensive coverage of Dystric Nitosols, with their high fertility and good structure, supports a wide range of crops, including cereals, legumes, root crops, and vegetables. Effective management practices for Dystric Nitosols include maintaining soil structure and organic matter content through crop rotation, cover cropping, and reduced tillage. These practices help prevent soil erosion, enhance water retention, and promote healthy soil microbiota. In contrast, the limited area of Xanthic Ferralsols suggests these soils are less significant in terms of overall agricultural production. However, targeted management practices, such as agroforestry, liming to adjust soil pH, and incorporating organic matter through composting or green manuring, can enhance the productivity of Ferralsols, ensuring that even small areas contribute to the region's agricultural output.

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