



**Assessment of Slope Dynamics and Land Use Impact on Groundwater Recharge and Flood Risks: a case study of Bayelsa State, Niger Delta**

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**Abstract**

The Niger Delta region of Nigeria, characterized by low-gradient terrain, significantly influences groundwater dynamics and flood risks. This study focuses on the Kolokuma/Opokuma, Ogbia, and Yenagoa areas in Bayelsa State to assess the implications of slope variations and land use on these hydrological processes. Geographic Information System (GIS) techniques were utilized to analyze slope degrees, slope length and steepness factors, and Land Use and Land Cover (LULC) types across the study region. Slope analysis determined the distribution of slope degrees and steepness factors, while LULC analysis identified the dominant land cover types and their influence on hydrological processes. Slope analysis revealed that approximately 38.5% of the study area has a slope degree of 0 - 1.67°, indicating predominantly flat terrain. The steepness analysis showed that 94.5% of the area falls within the lowest category of steepness factors (0.00 - 6.77). LULC analysis highlighted that tree cover dominates (1625.45 km<sup>2</sup>), promoting groundwater recharge, while built-up areas (127.96 km<sup>2</sup>) contribute to increased flood risks. The findings emphasize the vulnerability of the region to flooding due to low-gradient slopes and significant built-up areas that reduce infiltration. The dominance of tree cover benefits groundwater recharge, but urban impermeable surfaces exacerbate flood risks, particularly in Yenagoa. This study underscores the need for integrated land use and flood management strategies in Bayelsa State to balance groundwater recharge with flood mitigation, highlighting the importance of preserving natural land cover for hydrological stability.

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## 1.0 Introduction

Groundwater is a critical component of the hydrological cycle, serving as a key source of fresh water for drinking, agriculture, and industrial purposes (Adebayo *et al.*, 2021). The sustainable management of groundwater resources is essential for ensuring the long-term availability of fresh water, particularly in regions that are vulnerable to water scarcity. To achieve this, it is crucial to understand the various factors that influence groundwater availability and quality, including topographic variables such as slope length and steepness, as well as LULC and management practices (Aladejana *et al.*, 2020; Ijioma, 2021).

Slope length and steepness are fundamental topographic factors that play a significant role in determining how water moves across the land surface and infiltrates into the groundwater system (Comegna *et al.*, 2020). These factors are often combined into the LS Factor, a key component in soil erosion models and hydrological assessments (Wang *et al.*, 2020). Slope length refers to the horizontal distance over which water flows between contour lines on the land surface. Longer slopes provide more opportunity for water to accumulate, increasing its momentum and, consequently, the potential for soil erosion (Zhao *et al.*, 2022). On the other hand, slope steepness describes the degree of incline of the land surface, with steeper slopes leading to faster surface runoff. This rapid runoff decreases the time available for water to infiltrate the soil, reducing groundwater recharge potential and increasing erosion risks (Dai *et al.*, 2018).

In practical terms, areas with steeper slopes and longer slope lengths typically experience increased surface runoff and reduced groundwater recharge. The swift movement of water across steep terrains limits infiltration time, leading to higher erosion rates and decreased soil moisture levels, both of which negatively impact groundwater recharge (Dean

*et al.*, 2015). Conversely, flatter slopes with shorter lengths are more conducive to groundwater recharge because the slower movement of water allows for greater infiltration through the soil profile (Brito *et al.*, 2020).

LULC are critical in influencing groundwater recharge and the overall hydrological balance of an area (Akaolisa *et al.*, 2023). LULC types, such as forests, grasslands, agricultural fields, and urban areas, interact with topographic features like slope length and steepness to either facilitate or hinder groundwater recharge. Vegetation, a key component of LULC, plays a significant role in groundwater recharge by protecting the soil surface from direct rainfall impact, reducing soil erosion, and enhancing water infiltration (Ashaolu *et al.*, 2019).

Vegetative cover, including trees, grasslands, and agricultural crops, acts as a natural barrier that intercepts rainfall, absorbs water, and stabilizes the soil with its root systems. This process mitigates surface runoff, promotes water infiltration, and ultimately contributes to groundwater recharge (Olorunfemi *et al.*, 2018). Forests and grasslands, with their dense root systems and organic matter, allow rainwater to percolate through the soil, increasing groundwater recharge rates. In contrast, urban areas with impermeable surfaces, such as roads and buildings, prevent water from infiltrating the soil, leading to increased surface runoff and reduced groundwater recharge (Aluko & Igwe, 2017).

The distribution of LULC types across a landscape significantly impacts groundwater recharge. Areas dominated by vegetation, such as forests and grasslands, typically exhibit higher rates of infiltration and groundwater recharge. In contrast, regions with extensive urban or built-up areas are more prone to surface runoff, which not only reduces groundwater recharge but also increases the risk of flooding, particularly during heavy

rainfall events (Dean *et al.*, 2015). Moreover, agricultural lands can either enhance or reduce groundwater recharge depending on the management practices employed. Practices such as crop rotation, cover cropping, and reduced tillage can improve soil structure, increase infiltration, and promote groundwater recharge. On the other hand, intensive farming practices that lead to soil compaction and the removal of vegetation cover can exacerbate runoff and reduce recharge potential (Ijioma, 2021).

The integration of slope length, steepness, and LULC factors into hydrological models and groundwater assessments provides valuable insights into the sustainability of water resources (Verma *et al.*, 2020). By considering these factors in water resource planning and management, stakeholders can develop strategies that promote sustainable land use, protect groundwater resources, and mitigate the impacts of soil erosion and flooding. For instance, in regions with steep slopes and significant erosion potential, targeted soil conservation measures and vegetation management are essential for mitigating surface runoff and enhancing groundwater recharge. In flatter areas with adequate vegetation cover, maintaining effective land management practices can maximize groundwater infiltration and minimize the risk of soil erosion (Dai *et al.*, 2018).

The LS factor, when combined with LULC data, can serve as a powerful tool for predicting erosion potential and guiding land management practices. By analyzing the LS factor alongside LULC, it is possible to identify areas that are at high risk for erosion and low groundwater recharge (Chen *et al.*, 2021). This information can be used to implement targeted land management strategies, such as reforestation, the creation of buffer zones, and the adoption of sustainable agricultural practices, to enhance groundwater recharge and reduce erosion

(Wang *et al.*, 2020). The relationship between slope, LULC, and flood risk is particularly important in regions like the Niger Delta, where low-gradient terrain and extensive floodplains are common. In such areas, even slight variations in slope and land cover can have significant impacts on the movement of water across the landscape and its infiltration into the groundwater system (Dan-Jumbo *et al.*, 2018). Steeper slopes, particularly when combined with impermeable surfaces in urban areas, can lead to rapid surface runoff and increased flood risk. Conversely, flatter areas with dense vegetation cover are more likely to experience slower runoff and higher groundwater recharge rates, reducing the risk of flooding (Brito *et al.*, 2020). Understanding the interplay between slope, LULC, and hydrological processes is crucial for effective flood management and groundwater conservation in flood-prone regions. By incorporating slope and LULC data into flood risk assessments and groundwater management plans, it is possible to develop more accurate predictions of flood events and identify areas that are most vulnerable to flooding and groundwater depletion (Aladejana *et al.*, 2020).

Existing research has primarily focused on the broader Niger Delta, emphasizing general environmental and hydrological challenges such as erosion, subsidence, and flooding. Studies have often highlighted the vulnerability of the Niger Delta to climate change and sea-level rise, which exacerbate flood risks (Chioma *et al.*, 2019; Idowu & Zhou, 2019; Week & Wizer, 2020). However, most of these studies have concentrated on coastal areas and major urban centers like Port Harcourt, leaving substantial knowledge gaps in the inland areas of Bayelsa State. The specific interactions between slope dynamics, land use, and hydrological processes in Bayelsa State remain underexplored, particularly in the Kolokuma/Opokuma, Ogbia, and Yenagoa regions. Previous research has generally lacked a fine-

grained analysis of how slope variations and land use patterns directly influence groundwater recharge and flood risks in these areas. While some studies have addressed land use changes and their environmental impacts, they have often treated slope dynamics and hydrological processes as secondary considerations, leading to a fragmented understanding of their interplay.

The assessment of slope length, steepness, and LULC is essential for understanding and managing groundwater resources and flood risks. These factors significantly influence the movement of water across the land surface, its infiltration into the groundwater system, and the overall hydrological balance of a region. By integrating these variables into hydrological models and water resource management strategies, it is possible to promote sustainable land use, enhance groundwater recharge, and mitigate the impacts of erosion and flooding. This holistic approach is particularly important in regions like the Niger Delta, where the delicate balance between land cover, topography, and water resources is critical for sustaining both human and ecological systems. The aim of this study is to evaluate the slope degrees, slope length and steepness factors, and Land Use and Land Cover (LULC) in relation to groundwater recharge potential and flooding risks in the study area. The study utilized Geographic Information System (GIS) techniques to analyze slope variations and LULC types across the study region.

## 2.0 Location and Geology of the Study Area

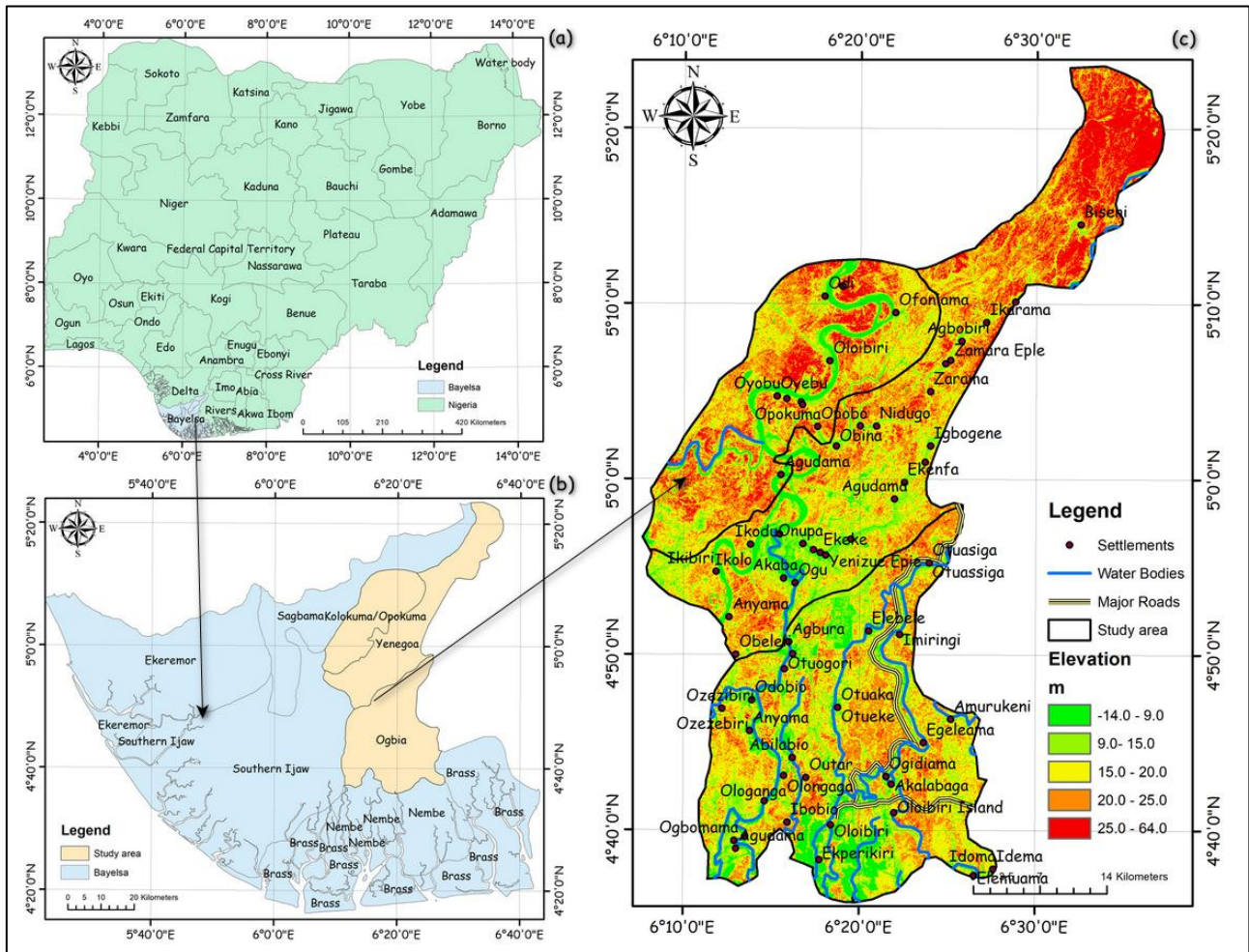
Bayelsa State, and particularly the study areas, is characterized by a combination of rural and urban settings. Yenagoa, the capital of Bayelsa State, is the most urbanized of the three LGAs, serving as a hub for political and economic activities. It is home to a growing population, with increasing urban sprawl and infrastructure development. Despite this urbanization, rural settlements are prevalent, especially in

Kolokuma/Opokuma and Ogbia (Brisibe & Pepple, 2018). These rural areas are primarily agrarian, with communities engaging in fishing, farming, and palm oil production. The rural-urban dynamics in these LGAs reflect the broader socio-economic patterns in the Niger Delta, where urban centers are often concentrated near government seats or resource extraction sites, while rural areas remain less developed, with limited access to basic amenities (Brisibe & Pepple, 2018). The study areas are located within the geographical coordinates of approximately 4°30' to 5°30' N latitude and 6°00' to 6°30' E longitude, as shown in Figure 1. These coordinates place the LGAs within the central portion of the Niger Delta, an area renowned for its rich biodiversity, significant oil and gas reserves, and complex socio-economic dynamics.

The Niger Delta's low-lying topography is well represented in the terrains of Kolokuma/Opokuma, Ogbia, and Yenagoa. These areas feature flat to gently undulating landscapes, with elevations ranging from 0 to 50 meters above sea level. This low elevation is typical of the deltaic environment, shaped over time by sediment deposition from the Niger River (Kenibolayefa & Innocent, 2018). The landscape is dotted with creeks, rivers, and swamps, creating a complex network of water bodies that define the region's geography. The abundance of these water bodies makes the area particularly susceptible to flooding, especially during the rainy season, which presents a significant environmental challenge to the residents. In Kolokuma/Opokuma, the Nun River flows through the area, providing a crucial water source for agriculture and domestic use. Ogbia, with its numerous creeks and rivers, includes Kolo Creek, historically significant as the site of Nigeria's first commercial oil discovery (Onu *et al.*, 2013). Yenagoa, the capital city, is situated along Epie Creek, which meanders through the city and its surrounding wetlands. These water bodies are

vital to the local economy, supporting fishing, agriculture, and transportation. However, they also present challenges, such as seasonal flooding and water pollution, particularly from oil spills and industrial discharges (Onu *et al.*, 2013). The climate in these areas is tropical, characterised by high temperatures and humidity year-round. The region experiences a rainy season from April to October, followed by

a dry season from November to March. During the rainy season, the area receives heavy rainfall, with annual precipitation ranging from 2,500 mm to 4,000 mm (Erebi *et al.*, 2020). This significant rainfall contributes to lush vegetation and extensive wetlands but also exacerbates problems like soil erosion, flooding, and nutrient leaching, which can negatively impact agriculture and food security.



**Figure 1:** Map of (a) Nigeria (b) Bayelsa and (c) the study area

Geologically, Kolokuma/Opokuma, Ogbia, and Yenagoa are representative of the Niger Delta, which is primarily composed of tertiary sediments deposited by the Niger River and its tributaries. These areas' subsurface geology consists of three primary lithostratigraphic units. The Benin Formation, the youngest, consists mainly of continental sands, gravels,

and silts and forms the uppermost layers of the delta, serving as a crucial groundwater resource (Karo *et al.*, 2019). Beneath it lies the Agbada Formation, characterised by alternating layers of sandstone and shale, which serves as the primary reservoir for oil and gas in the Niger Delta, making it economically significant. The deepest of the formations, the Akata Formation,

is composed mainly of marine shales and acts as the source rock for hydrocarbons in the region (Kouadio *et al.*, 2020).

### 3.0 Materials and Methods

#### 3.1 Datasets Used

This study utilized four Digital Elevation Models (DEMs) from the Shuttle Radar

Topography Mission (SRTM) to perform topographic characterization and analyze land surface and slope. LULC data were generated using Sentinel-2 imagery, covering the period from 2017 to 2023 as shown in Table 1. These datasets were integral to the study, serving as the foundation for various analyses and modeling tasks.

**Table 1:** Datasets used in this study

Parameters	Data Source	Year	Resolution (m)	Sources
LULC	Sentinel-2 imagery	2017 – 2023	10	<a href="https://livingatlas.arcgis.com/en/apps/">https://livingatlas.arcgis.com/en/apps/</a>
LS and slope	SRTM	2021	30	<a href="earthexplorer.usgs.gov">earthexplorer.usgs.gov</a>

The combination of DEMs and LULC data provided a comprehensive understanding of the study area's terrain and land use patterns. The high-resolution Sentinel-2 imagery enabled detailed mapping of LULC changes, while the SRTM data, with a 30-meter resolution, offered accurate insights into the region's elevation and slope characteristics.

#### 3.2 Slope Length and Steepness Factors (LS Factor)

Topography plays a crucial role in soil erosion, primarily through the Slope Length (L) and Slope Steepness (S) Factors, collectively referred to as the LS Factor. This factor evaluates how slope length and steepness influence erosion by comparing the erodibility of a specific land parcel to a standard reference plot (Bircher *et al.*, 2019). The LS Factor is determined using Digital Elevation Models (DEMs) and involves parameters such as flow accumulation, grid slope, and pixel size. The Unit Stream Power Erosion and Deposition (USPED) method is commonly employed to calculate the LS Factor, using raster calculations between the flow accumulation and the slope of the watershed.

$$L = (m + 1) \frac{\lambda_A}{22.1}^m \quad (1)$$

where  $\lambda_A$  represents the area of upland flow, and 22.1 meters is the standard unit plot length used for reference. The variable  $m$  is adjustable based on the soil's susceptibility to erosion, allowing the equation to account for different soil types and their erosion potential.

$$S = \left( \frac{\sin(0.01745 \times \theta_{deg})}{0.09} \right)^n \quad (2)$$

$\theta$  is measured in degrees, with the equation incorporating a slope gradient constant of 0.09. The variable  $n$  is adjustable based on the soil's susceptibility to erosion, allowing the model to account for varying erosion potentials across different soil types. Therefore:

$$LS = (m + 1) \frac{\lambda_A}{22.1}^m \times \left( \frac{\sin(0.01745 \times \theta_{deg})}{0.09} \right)^n \quad (3)$$

This assessment of topographical impact on erosion identifies areas requiring slope-related erosion control, like terracing and contour farming. The LS Factor is crucial for soil conservation planning, enabling targeted interventions in erosion-prone regions.

#### 3.3 LULC Classification

The preprocessing of satellite images involved both radiometric and geometric corrections to enhance their accuracy and reliability. Radiometric corrections were applied to adjust for sensor noise and atmospheric interference,

ensuring that the pixel values accurately represent the Earth's surface. Geometric corrections were performed to align the images with real-world coordinates, eliminating distortions caused by the satellite's movement (Aisabokhae & Osazuwa, 2021). After preprocessing, the images were subjected to supervised classification to categorize them into different LULC types. Training samples representing distinct land cover classes, such as vegetation, water bodies, and urban areas, were collected to guide the classification process. A maximum likelihood classifier was employed, which assigns each pixel to the class it most likely belongs to based on the training samples (Afolabi *et al.*, 2021). The classification accuracy was evaluated using ground truth data and metrics such as the Kappa coefficient, which quantifies the level of agreement between the classified results and the reference data.

## 4.0 Result and Discussion

### 4.1 Slope and LS Factor its impact on Groundwater Dynamics and Flooding

The slope analysis conducted for Kolokuma/Opokuma, Ogbia, and Yenagoa areas in Bayelsa State reveals significant variability in the slope degrees across the study region, with implications for both groundwater dynamics and flooding potential.

**Table 2:** Slope range and area cover of the study area

Slope (°)	Area (km <sup>2</sup> )
0 - 1.67	683.76
1.67 - 3.06	673.28
3.06 - 4.64	384.50
4.64 - 7.01	154.32
7.01 - 25.18	34.09

In Figure 2 and Table 2, the majority of the study area exhibits low slope degrees, with 683.76 km<sup>2</sup> (approximately 38.5%) of the total area falling within the 0 - 1.67° range. This gentle slope suggests a relatively flat terrain, which is characteristic of the Niger Delta region as also reported by Amadi (2020). Such

low-gradient areas are prone to water logging and flooding, especially during the rainy season (Chattaraj *et al.*, 2021; Zhang *et al.*, 2023). The relatively large area within the 1.67 - 3.06° range (673.28 km<sup>2</sup> or 37.9%) further emphasizes the dominance of low-gradient slopes in the region.

Moderate slopes between 3.06° and 7.01° are present but occupy significantly less area, with a total of 538.82 km<sup>2</sup> (30.3%). The steeper slopes, ranging from 7.01° to 25.18°, cover only 34.09 km<sup>2</sup> (1.9%) of the study area, indicating that steep terrain is minimal in the region. These steeper slopes are likely to influence localized runoff patterns and may contribute to erosion in specific areas (Olorunfemi *et al.*, 2020). However, their limited extent reduces the overall impact on the region's hydrology.

**Table 3:** LS factor and area cover of the study area

LS Factor	Area (km <sup>2</sup> )
0.00 - 6.77	1876.31
6.77 - 7.21	3.63
7.21 - 13.9	25.75
13.98 - 119.23	22.34
119.23 - 1754.68	1.97

Figure 3 and Table 3 provide a detailed breakdown of the slope length and steepness factors, which are crucial for understanding erosion potential and runoff characteristics. The vast majority of the study area (1876.31 km<sup>2</sup> or 94.5%) falls within the lowest category of slope length and steepness factors (0.00 - 6.77). This indicates that most of the terrains have gentle slopes with short slope lengths, further supporting the observation of a predominantly flat landscape (Igwe, 2015).

### 4.2 LULC Analysis and Its Impact on Groundwater Dynamics and Flooding

LULC 2023 analysis for the Kolokuma/Opokuma, Ogbia, and Yenagoa areas in Bayelsa State provides a comprehensive understanding of the distribution of various land cover types and their potential influence

on groundwater recharge and flooding. Table 4 summarizes the area coverage of different

LULC types within the study area, highlighting the dominance of certain land cover classes.

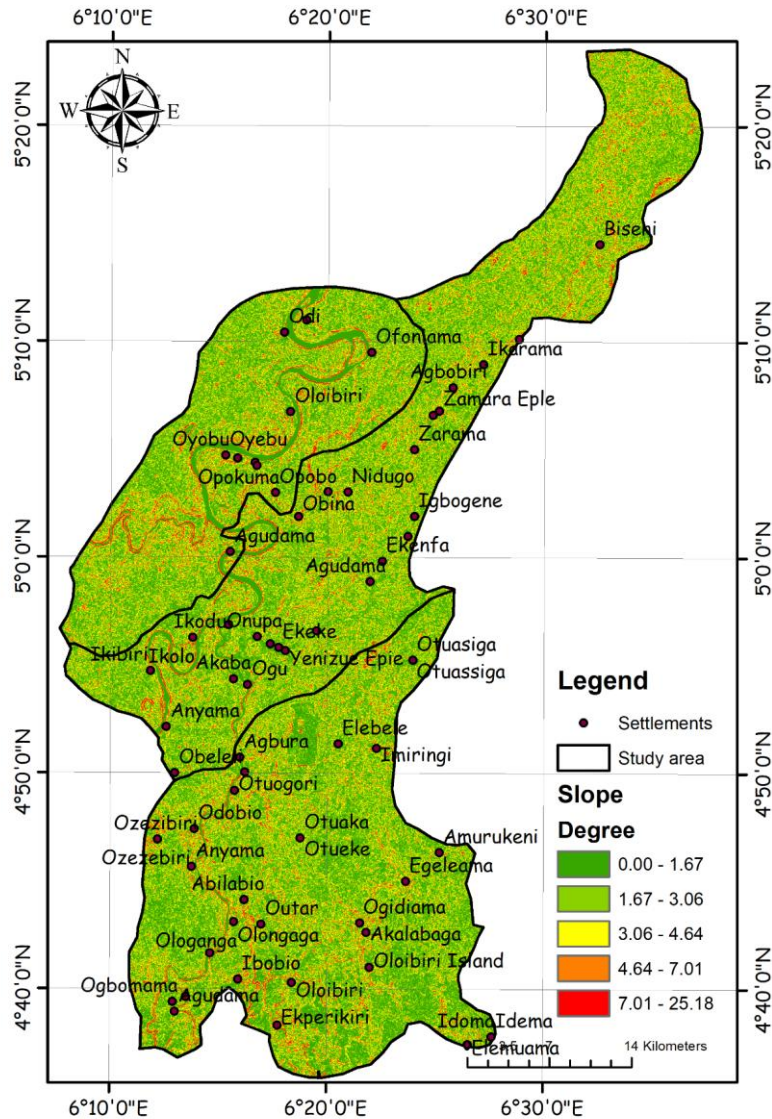


Figure 2: Spatial variation of slope within the study area

Figure 4 and Table 4 shows that the most extensive land cover type in the study area is trees, occupying 1625.45 km<sup>2</sup>, which accounts for a significant portion of the total land area. The prevalence of tree cover is crucial for maintaining the region’s hydrological balance, as it facilitates groundwater recharge by allowing for greater infiltration of rainwater. The tree cover also acts as a natural barrier against erosion, helping to stabilize the soil and reduce surface runoff, thereby mitigating flood risks (Ashaolu et al., 2019).

Table 4: LULC 2023 Types in the Study Area

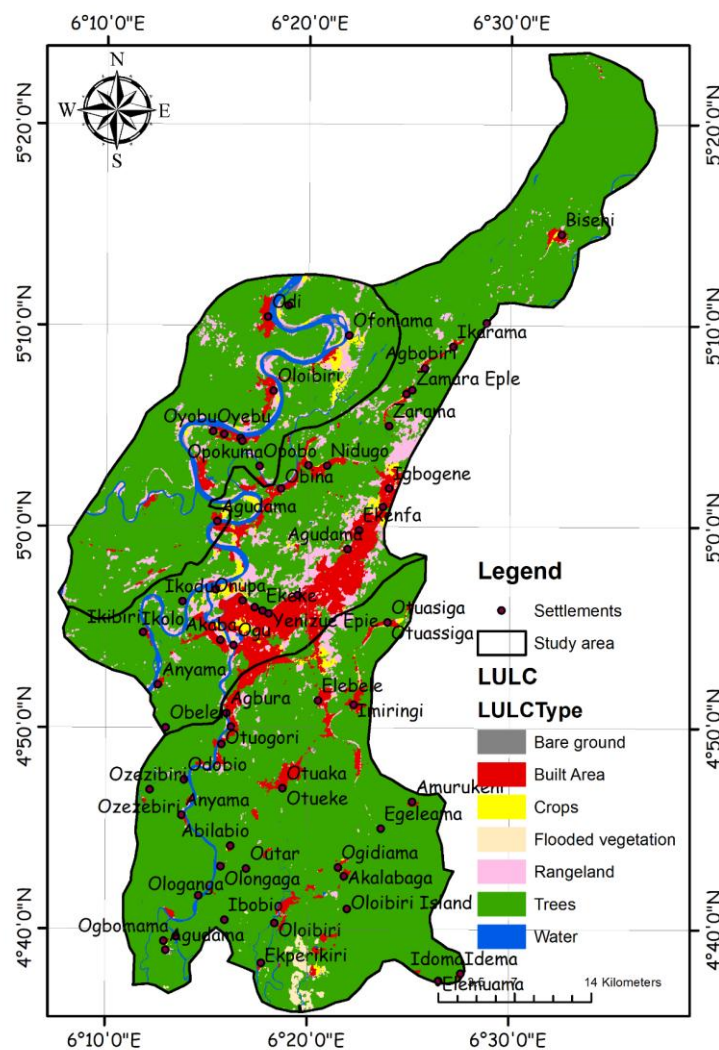
LULC 2023 Type	Area (Km <sup>2</sup> )
Water	88.17
Trees	1625.45
Flooded vegetation	6.09
Crops	25.31
Built Area	127.96
Bare ground	1.96
Rangeland	64.17

Water bodies cover 88.17 km<sup>2</sup> of the area, playing a vital role in the region's hydrology. The presence of water bodies, which include rivers, streams, and other aquatic systems,



suggests a high potential for groundwater recharge, particularly in areas where the water table is close to the surface. However, these areas are also prone to flooding, especially during periods of heavy rainfall or when upstream water levels rise. The connectivity between these water bodies and the surrounding land cover types influences both groundwater dynamics and the potential for flood events (Olokeogun *et al.*, 2020). The study area also contains 127.96 km<sup>2</sup> of built-up areas, which include urbanized zones, infrastructure, and

residential buildings. Built-up areas are impermeable surfaces that hinder groundwater recharge by reducing the amount of water that can infiltrate the soil. This land cover type increases surface runoff, contributing to higher flood risks, particularly in urban centers like Yenagoa. The impermeable nature of built areas exacerbates flooding, as rainwater is rapidly channeled into drainage systems, which may become overwhelmed during heavy storms (Chattaraj *et al.*, 2021).



**Figure 4:** Spatial map of LULC 2023 of the Study Area

Crops and rangelands together cover a relatively small portion of the area, with crops occupying 25.31 km<sup>2</sup> and rangelands covering 64.17 km<sup>2</sup>. While these land cover types are generally associated with some level of

groundwater recharge, their impact is less significant due to their limited extent. However, agricultural activities can influence local hydrology by altering the natural infiltration and runoff patterns, especially in areas where

irrigation is practiced or where the soil has been compacted by farming equipment.

Flooded vegetation, which occupies 6.09 km<sup>2</sup>, represents areas where vegetation is periodically submerged, indicating regions that are regularly inundated by floodwaters. This land cover type is directly influenced by flood events and can serve as an indicator of flood-prone zones. The presence of flooded vegetation highlights areas where groundwater recharge may be enhanced due to prolonged water presence, but also where flood risks are naturally higher. Bare ground, covering just 1.96 km<sup>2</sup>, represents areas with little to no vegetation. These areas are typically more susceptible to erosion and contribute to

increased surface runoff. The minimal extent of bare ground in the study area suggests that its overall impact on flooding and groundwater recharge is limited, but the LULC analysis underscores the complex interplay between land cover types and the hydrological processes within the study area. The extensive tree cover promotes groundwater recharge, while water bodies act as reservoirs that support both surface and groundwater systems (Ampe *et al.*, 2012). However, the presence of built-up areas introduces challenges for flood management due to reduced infiltration and increased runoff. Flooded vegetation zones further emphasize the area's most susceptible to flooding, particularly during the rainy season (Ren *et al.*, 2019).

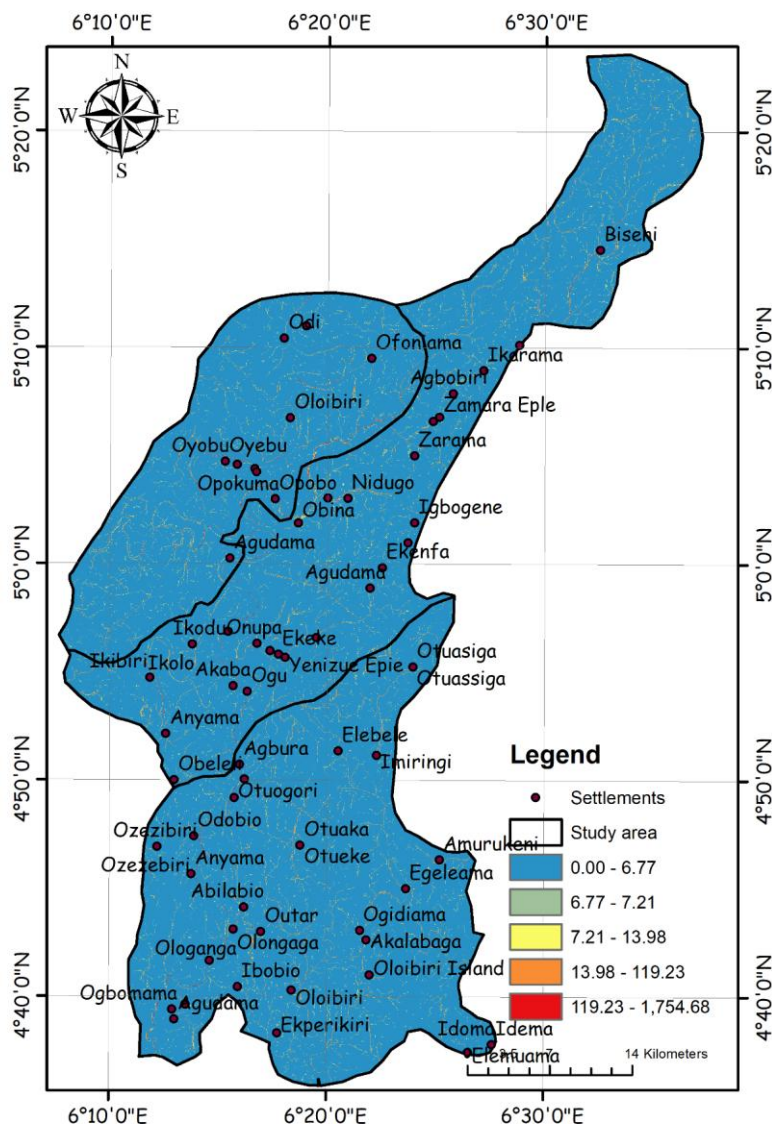


Figure 3: Spatial variation of LS factor within the study area

Only a small portion of the area (3.63 km<sup>2</sup> or 0.2%) falls within the 6.77 - 7.21 range, and similarly limited areas are observed in the higher ranges (25.75 km<sup>2</sup> or 1.3% within 7.21 - 13.9 and 22.34 km<sup>2</sup> or 1.1% within 13.98 - 119.23). The most extreme category (119.23 - 1754.68) covers just 1.97 km<sup>2</sup> (0.1%), indicating that the study area has very few regions with steep and long slopes.

The analysis of slope degrees and slope length and steepness factors provides valuable insights into groundwater behavior and flood risk within the study area. The dominance of low slopes across the region suggests that the natural drainage is likely to be poor, leading to significant water retention in the soil. This condition is conducive to groundwater recharge, as the slow movement of water allows more infiltration into the aquifer systems. However, it also heightens the risk of flooding, particularly in areas with slopes ranging from 0° to 3.06°. In regions with very low slope degrees (0 - 1.67°), the potential for surface water accumulation is high, increasing the likelihood of floods, especially during periods of heavy rainfall. The flat terrain limits the natural runoff, causing water to accumulate and inundate large areas, which is a common issue in the Niger Delta. The presence of moderate slopes (3.06 - 7.01°) and the steepest slopes (7.01 - 25.18°) may contribute to localized runoff, but their limited spatial extent suggests that their impact on regional flooding is minimal. The slope length and steepness factors further reinforce this observation. The predominance of low values indicates that most of the terrain is not prone to significant erosion, but the low slopes and short slope lengths exacerbate the risk of flooding by reducing runoff efficiency (He *et al.*, 2022). In contrast, the areas with higher slope length and steepness factors, although limited, may experience more rapid runoff and potential erosion, but these effects are likely to be localized and not

significantly alter the overall flood risk for the region.

## 5.0 Conclusion

The findings from the slope and LULC analyses for Kolokuma/ Opokuma, Ogbia, and Yenagoa areas in Bayelsa State reveal critical insights into the region's vulnerability to flooding and its potential for groundwater recharge. The predominance of low-gradient slopes, as indicated by the significant areas within the 0 - 1.67° and 1.67 - 3.06° ranges, suggests a landscape that is largely flat, which is typical of the Niger Delta. This flat terrain, while beneficial for groundwater recharge, also predisposes the area to water logging and flooding, particularly during heavy rainfall. The limited presence of steeper slopes reduces the overall erosion risk but could lead to localized runoff and erosion issues in specific areas.

The LULC analysis further emphasizes the region's susceptibility to flooding, particularly in built-up and flooded vegetation areas. The extensive tree cover is crucial for sustaining groundwater levels by promoting infiltration, but the presence of impermeable built-up areas presents challenges for flood management. These areas increase surface runoff, which can overwhelm drainage systems and exacerbate flooding in urban centers like Yenagoa. Water bodies, which play a dual role in groundwater recharge and flood risks, require careful management to balance their benefits and potential hazards. The study provides novel insights into the interplay between slope dynamics, land use, and hydrological processes in Bayelsa State, Niger Delta. The analysis reveals that the region's predominantly flat terrain, with 38.5% of the area having slopes between 0° and 1.67°, significantly influences groundwater recharge and flood risks. This low-gradient landscape, coupled with extensive tree cover, facilitates groundwater infiltration but also heightens flood susceptibility during heavy rainfall. The study's findings underscore the critical need for tailored flood management

strategies in this unique geological and hydrological context. To mitigate flooding and enhance groundwater recharge, it is recommended to implement sustainable land use planning that prioritizes the preservation of tree cover and the careful management of built-up areas. Additionally, improving urban drainage infrastructure is crucial to reducing flood risks in vulnerable areas.

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