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Urban Flood Risk Assessment in Shomolu Local Government Area, Lagos State, Nigeria

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ABSTRACT

This study assessed urban flood risk in Shomolu Local Government Area (LGA), Lagos State, Nigeria using geospatial techniques. The research aimed to examine the factors influencing flooding and determine the extent of flood risk zones in the study area. Data were sourced from Digital Elevation Model (DEM), soil data, rainfall data, and Landsat ETM+ for the study. The study utilized techniques such as Analytical Hierarchy Process (AHP) and weighted overlay analysis in ArcGIS 10.8 software to create a flood risk map of Shomolu LGA based on six influential factors, which included elevation, slope and soil types, drainage density, proximity to waterbody/river and rainfall distribution. Findings revealed that rainfall intensity was the most significant factor contributing to flood risk in the study area, with a weight of 30.8% followed by slope with 20% weight while drainage density had the lowest influence with a weight of 9.3%. The findings further revealed that 34.9% of the study area are high flood risk zones, while moderate and low risk zones constitute about 40.3% and 24.8% respectively. The study concluded that areas low-lying areas with high rainfall and areas along rivers channels are more prone to flooding than those at higher elevations. It is therefore recommended that urban planners improve land use planning and strictly implement regulations on building codes, as well as thoroughly inspect building standards within the high-risk zones identified in this study.

INTRODUCTION

Floods are the most common natural disasters; their frequency, magnitude, and the cost of damage are on the rise all over the world (Yang *et al.*, 2020). Flooding is a general temporary condition of partial or complete inundation of normally dry areas from the overflow of inland or tidal waters, or from unusual and rapid accumulation or runoff (Jeb & Aggarwal, 2008). According to the European Commission (2007), a flood can be defined as a natural phenomenon that results in temporary submerging with the water of land that does not occur under normal conditions. Flooding occurs when natural or man-made water bodies cannot sufficiently transport or hold excess water generated by storms or other sources, thereby overflowing their normal beds to flood nearby lands (Ogwuche & Abah, 2014). Although floods are natural disasters, they can be aggravated by human activities such as overcrowding, indiscriminate dumpsites, poor and malfunctioning drainage systems, unplanned housing schemes, and rising sea levels due to global warming, thereby leading to an increasing trend in flood disasters in coastal areas. The cumulative effects are alarming leading to retardation in both individual and communal levels (Wizor & Mpigi, 2020; Egbuna & Eyare, 2026)

Urban flooding refers to the overflow of water onto land that is normally dry in urban areas, primarily caused by excessive rainfall or other natural phenomena that overwhelm the existing drainage systems (Qin, 2020; Atoki & Ibraheem, 2026). This can lead to significant damage, disruption, and health hazards in city environments. Urban flood problems are a global experience, but management practices differ according to prevailing technologies and aptness in planning and implementation (Buba *et al.*, 2026). These experiences are worse in third world cities, where unplanned and uncoordinated development is prevalent (Olajuyigbe *et al.*, 2012). The causes of urban flooding include surcharges in water level due to natural or man-made construction on flood paths, sudden dam failure, inappropriate land use, mudflow, inadequate drainage capacity to cope with urbanization, excess encroachment in floodways, ice jams, rapid snowfall, deforestation of catchment basins, reclamation, construction sites, and solid waste (Nwafor, 2006; Javadinejad, 2022).

Globally, flooding has displaced more people than any other hazard or disaster, and the number of flood disasters that occur and the cost of the damage they cause are increasing (Kundzewicz *et al.*, 2013). Heavy floods occurred in Pakistan, India, and China in the summer of 2010; Colombia from October to December 2010; and Australia during the Austral summer (2010) (Kundzewicz *et al.,* 2012). The maximum estimated annual damage caused by river flooding in China amounted to a total loss of US$ 51 billion, while there were nearly 2000 immediate fatalities from monsoonal flooding in Pakistan (Syvitski & Brakenridge, 2013). In 2011, severe floods were reported in African countries such as Mozambique, Namibia, South Africa, and Uganda. The major forms of flooding include coastal, river, and urban flooding

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(Oriola, 1994; Okoduwa, 1999; Folorunso & Awosika, 2001; Olosunorisa, 2004).

Remote Sensing is a technology used to gather spatial information to identify, classify, map, monitor, plan, mitigate, and manage natural disasters (Machireddy, 2023; Krichen *et al.*, 2023). Remotely sensed imagery and Geographical Information Systems (GIS) can be very effective for identifying the spatial components of floods for management (Leeonis *et al.*, 2024). During the past decades, airborne and space borne remote sensing technology, along with GIS, have become the key tool for flood monitoring (Janga *et al.*, 2023). Remote sensing offers a synoptic view of the spatial distribution and dynamics of hydrological phenomena such as floods. They are used to measure and monitor the extent of flooded areas, providing a quantifiable estimate of the land area and infrastructure affected by flooding (Izinyon, 2011). The main advantage of using GIS for flood analyses is that it not only generates a visualization of flooding, but also creates the potential to further analyze the damage extent of the event (Islam & Majumder, 2026; Wang & Xie, 2018), as well as maps that can support planning and development by identifying high-risk locations and steering development away from these areas (Almouctar *et al.*, 2024). Thus, remote sensing is a vital tool for flood risk assessment.

Flooding in Lagos State is predominantly due to its geographical location and high rate of commercialization and urbanization (Danladi *et al.*, 2024; Adegun, 2023). There has been a high rate of urbanization in the Shomolu Local Government Area (LGA) of Lagos State, with increasing housing construction and encroachment on open spaces and wetlands. The generally low-lying terrain of the area, coastal influences on its microclimate, heavy precipitation, blockage of drainage, and occasional release of water from the Oyam Dam all coalesce to exacerbate flood problems in the area (Ilesanmi, 2014). Lagos State suffers from incessantly unmitigated flooding, often resulting in disruption of communication masts, structural damage to buildings, and loss of lives and property. The 'century' flood of July 2011 as well as the yearly occurrences afterwards in the study area causes significant damage to the environment (Ibeabuchi, 2023). Therefore, it becomes pertinent for this study to adopts Remote Sensing and Geographic Information System (GIS) in assessing urban flood risk in Shomolu LGA, Lagos State, Nigeria.

MATERIALS AND METHODS

Study Area

The Shomolu Local Government is one of the LGAs in Lagos State. Shomolu Local Government Area (LGA) lies between Latitudes 6°31'30 N - 6°42'30''N of the Equator and Longitudes 3°22'E - 3°24'E of the Greenwich Meridian. It occupies an area of 1465.72 Ha (Adeneran, 2011). Shomolu LGA is bounded to the North and East by Kosofe LGA, South by Lagos Mainland and to the West by Mushin LGA as shown in Figure 1.

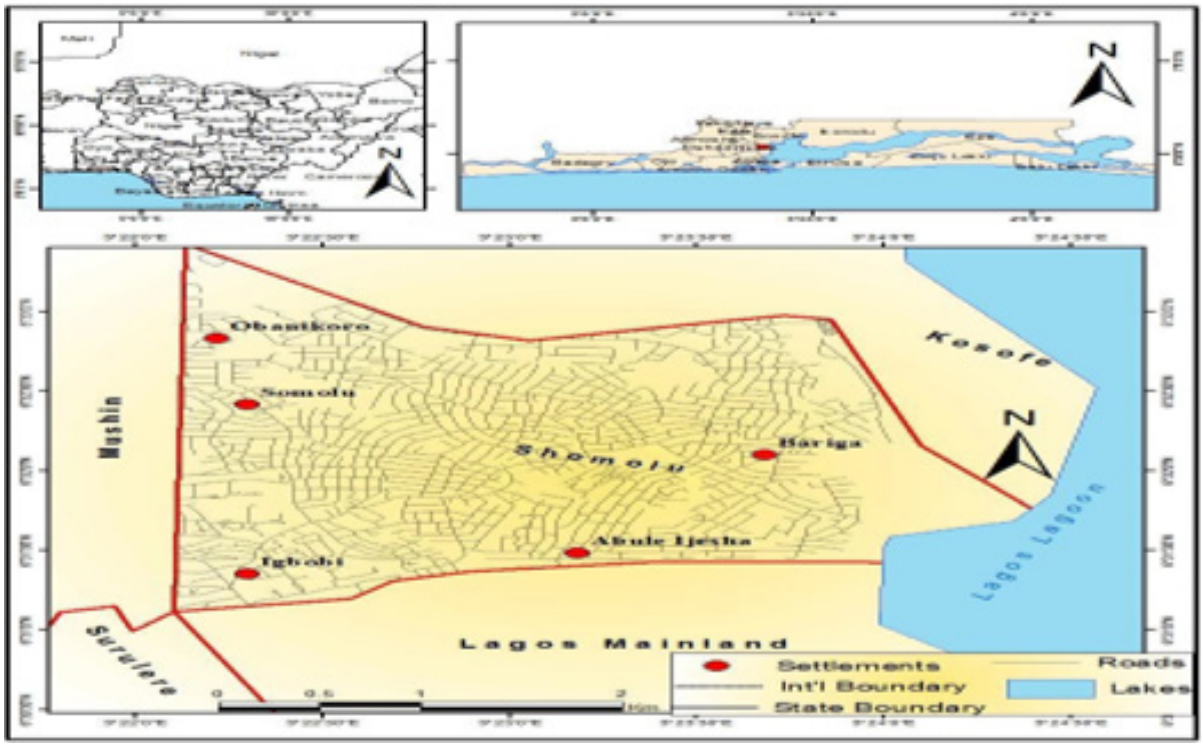


Figure 1: Shomolu Local Government Area

Data Types, Sources and their Uses

The types, sources and used of data acquired are summarized in Table 1.

Data Processing

This involved a stepwise arrangement and organization of acquired data in a manner that was appropriate for analysis.

Table 1: Types and Sources of Data Used for the Study

S/No	Type of Data	Source	Purpose
1.	Administrative map of Shomolu LGA 1:100,000	Ministry of Lands and Survey, Lagos State	To identify spatial features like roads, rivers, residential area,
2.	SRTM-DEM	https://search.earthdata.nasa.gov	For creation of Slope and drainage density maps
3.	SPOT-5 (0.5m) 23/08/2023	https://earthexplorer.usgs.gov/	Production of Land use/ land cover map
4.	Average annual rainfall (2014-2025)	Ikeja, Oshodi, and Ibadan meteorological stations	For mapping rainfall distribution and soil texture of the study area.
5.	Soil maps	National Geological Survey	To identify the soil types in the study area

Source: Authors Compilation (2026)

Geo-Referencing

The first step in processing the raw data is geo-referencing of different datasets for comparison and overlay. This is the process of assigning real-world coordinates to each pixel of a raster image. This involved importing the scanned copy of the administrative map into the GIS environment, and the coordinates obtained from the markings on the map image were used to georeferenced the map.

Sub-Setting

Sub-setting is a process involving the extraction of an Area of Interest (AOI) from the main data. The SRTM DEM and administrative map of the study area were clipped by masking the boundary area of the study area with the shapefile of Lagos state concurrently using the clipping toolset in the ArcGIS environment to subset the required data. The soil map of the area of interest was also clipped out using the boundary of the study area.

Preparation of Elevation and Slope Map

To prepare the elevation and slope map of the study area, the digital elevation model (DEM) data was analysis, all depressions have to be filled, and such depressions are called sinks. The DEM data were radiometrically corrected to remove speckle noise from the image, and a DEM was used to generate the slope and elevation map (Figure 2b and c). The DEM data provides information on the elevation of the terrain at regular intervals, such as 10-meter intervals.

Preparation of Rainfall Map

The rainfall distribution (Figure 2a) of the study area was generated from rainfall data of three meteorological stations: Ikeja, Oshodi, and Ibadan, which covers Shomolu LGA and its Environs. The record for a period of ten (10) years (2014-2024) was collected and interpolated in the spatial analyst tool of ArcGIS 10.3. The rainfall data obtained from the NIMET station were skewed against data abnormalities and were further structured into average yearly rainfall data, which were used to create a rainfall map that served as an input for data analysis.

Preparation of Proximity to Rivers Layer

The rivers in the study area were digitized from open street map and a scanned copy of the administrative map of the study area which was imported and georeferenced in the ArcGIS 10.8 environment and on-screen map digitization was performed to delineate the rivers and their tributaries for further analysis. Euclidean distance tool in ArcGIS 10.8 environment was used to indicate the different flood risk zones based on their proximity to river channel as presented in Figure 2(f).

Preparation of Soil Map

The soil map (Figure 2e) was georeferenced into a digital format using the ArcGIS environment. Data sub setting was then performed by clipping the soil map to align with the administrative boundary of Shomolu LGA, isolating the study area.

Preparation of Drainage Density

Drainage networks were extracted from SRTM DEMs and hydrological analysis was done to extract the flow direction and flow accumulation layers. A threshold for flow accumulation was applied to define stream initiation points and delineate the drainage network. Drainage density was computed as the total length of drainage channels within a unit area. Figure 2(d) shows the drainage density map of the study area.

Method of Data Analysis

The relative importance values were determined with Saaty's 1-9 scale (Table 2) where a score of 1 represents equal importance between the two attributes, and a score of 9 indicates the extreme importance of an attribute compared to the other one (Ogwuche & Abah, 2014).

The Reclassify tool was employed to categorize each variable's attributes based on their impact on flood susceptibility, rated on a scale of 1 to 9. The classification system assigns higher scores to areas with greater flood risk, with 9 indicating Very High-risk locations and 1 indicating Very Low-risk locations. The reclassified maps illustrating flood risk levels are presented along with Tables of the weight and the area. Spatial overlay analysis

Table 2: Procedure of Assigning Weightages in AHP

Scale	Degree of preference	Explanation
1	Equal importance	Two elements contribute equally to the objective
3	Moderate importance	Experience and judge slightly favour one element over another
5	Strong or essential importance	Experience and judgment strongly favour one element another
7	Very strong importance	One element is favoured very strongly over. Its dominance is demonstrated in practice
9	Extreme importance	The evidence favouring one element over another is of the highest possible order of affirmation,
2,4,6,8	Values for inverse comparison	Can be used to express intermediate values

Source: Saaty and Vargas (1991)

was performed to combine multiple layers to identify areas prone to flooding, proximity analysis to determine distances between features (e.g., rivers, streams) and flood-prone areas, network analysis to analyze river networks and drainage patterns and topographical modelling to determine the slope and elevation of the area using ArcGIS 10.8 software. The weighted overlay tool in ArcGIS 10.8 environment was used to combine the six flood risk indicators and produce a flood risk map of the study area.

RESULTS AND DISCUSSION

Average Annual Rainfall

Figure 3 reveals that about 31.9 % of the area have an average rainfall distribution between 3061.63 and 3176.54mm while 39.9% experience between 2946.73 and 3061.62mm average annual rainfall. The southern region of the study area receives the highest rainfall amounts, making it more prone to flooding than the northern region. This can be attributed to its proximity to the ocean.

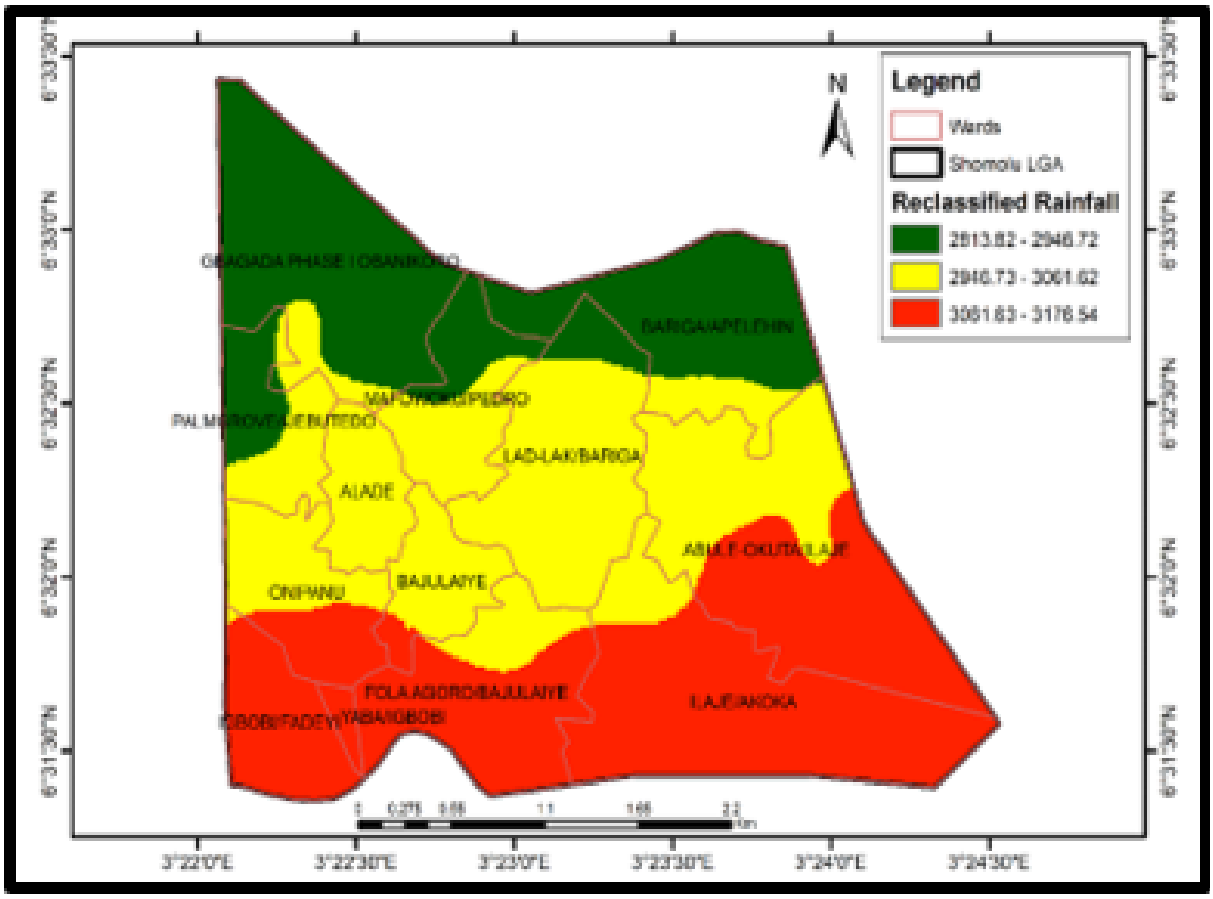


Figure 2: Reclassified Rainfall Distribution Maps of Shomolu LGA

Elevation

Figure 4 shows the reclassified flood risk zones based on elevation in the study area. It is obvious that 29.8% of the study area has a high elevation of -5.2 to 6.3m indicating that a significant portion of the area is relatively depressed or flat. This suggests that water accumulation in this area

may be high, potentially leading to flooding in lower-lying areas. This is followed by 48.8 percents which has 6.4 to 14.7m indicating a more flat or gradient terrain which may lead to the accumulation of water and flooding, as water may not drain efficiently. The combination of hilly and flat terrain may increase flooding risk, as water may flow from higher elevations to lower areas, potentially causing flooding and damage (Legese *et al.*, 2020). The flat terrain may lead to water accumulation, increasing the risk of flooding and waterlogging in certain areas, especially during heavy rainfall events.

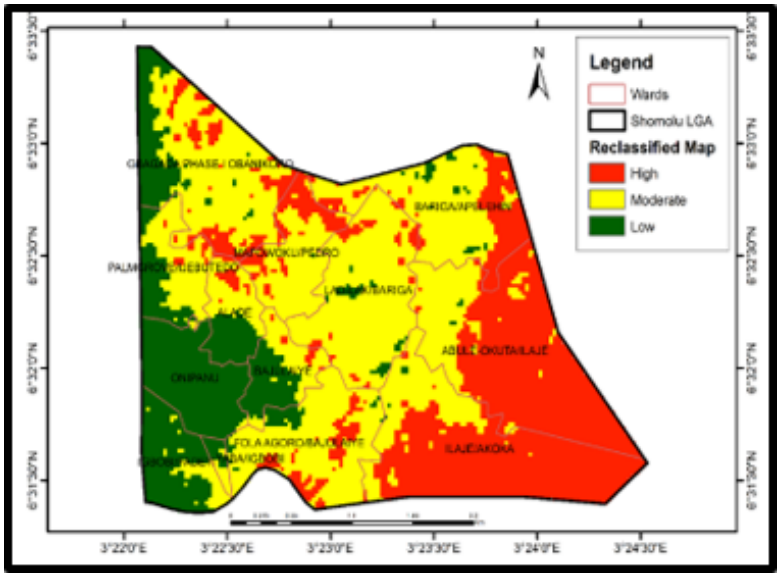


Figure 3: Reclassified Elevation of Shomolu LGA

Slope

As shown in Figure 5, it can be seen that the slope value ranges from 0 to 10.72 degrees, while areas of high slope amounts are scattered over the map with the largest coverage found in the south. This confirms the FDALR (2022) assertion that the area consists of nearly levelled land to gently undulating plains with scattered rock outcrops. In relation to flooding, flat areas where the slope is low are capable of accumulating rainfall runoff, which in turn facilitates the accumulation of water on the surface, whereas in elevated areas where the slope is high, there is high runoff and low accumulation. The sloping terrain can lead to rapid water runoff, potentially causing erosion and flooding in low-lying areas (Hsiao *et al.*, 2021).

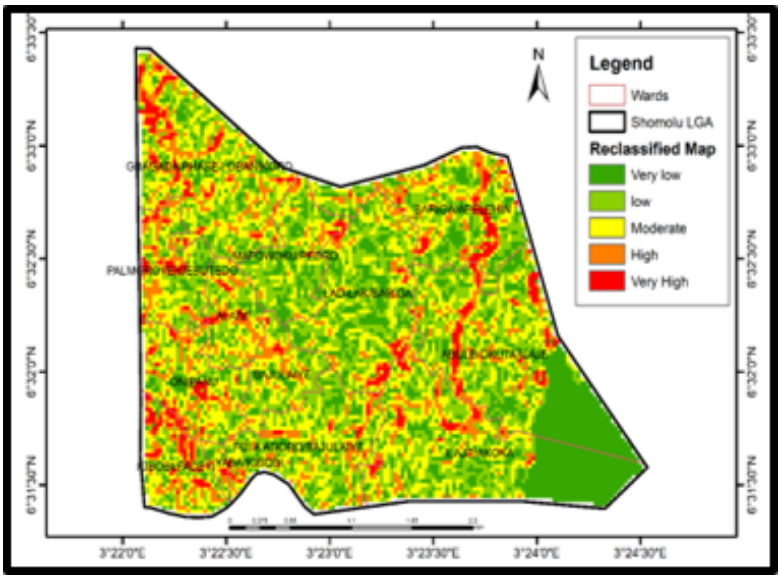


Figure 4: Reclassified Slope Map of Shomolu LGA

Drainage Density

Figure 6 showed that drainage density of the area ranges from 0 to 2690.85Km/Km2 with major river channels having higher drainage density. The very high-risk zones are located around the intersections of major rivers tributaries in the study area. The drainage density of Shomolu as presented in Figure 4.8 showed that the major drainage basin present in the study area is the Lamurde

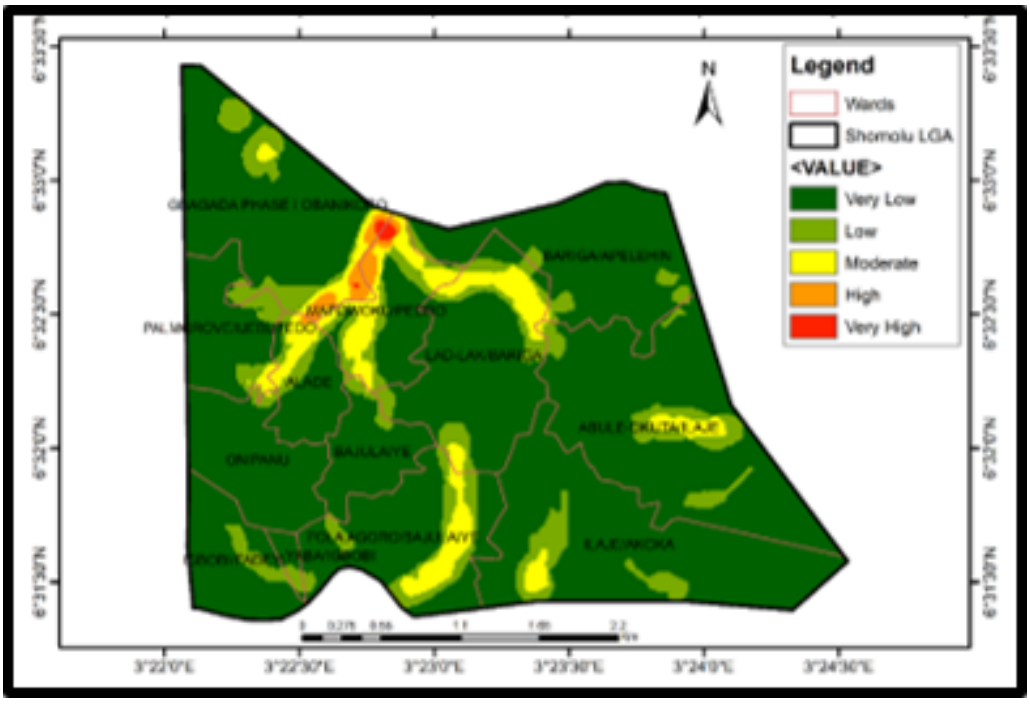


Figure 5: Reclassified Drainage Density Map of Shomolu LGA

River, which flows southward into the lagoon. It is worth noting that the study area is characterized by many first-order streams that drain directly into Lagos Lagoon.

Soil Types

Results showed that clay soil which was identified as the very high-risk soil texture accounted for about 63.7% of the study area. This included areas such as Onipanu, Bariga, Alade Mafowoku and Bajulaiye. It was also revealed that sandy loam soil accounted for 15.1% area which occupied most of northern part of the study area northward to like Gbagada ward. Coastal plain sand occupied the remaining 21.2%, this was found in the southernmost part of the study area boarding the lagoon which includes areas Akoka and Ilaje. The reclassified soil map of Lagos State is presented in Figure 7.

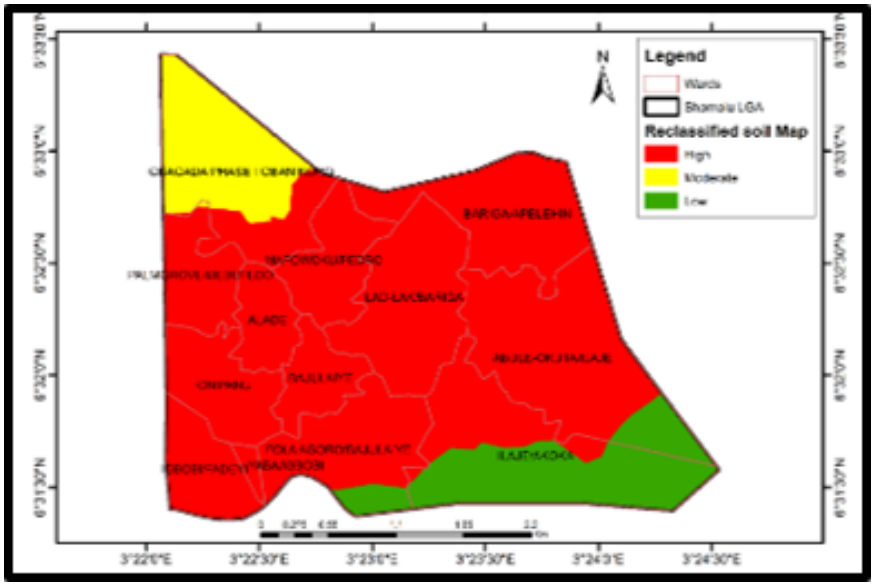


Figure 6: Reclassified Soil Map of Shomolu LGA

Proximity to Waterbody/River

According to Figure 8, about 31.3% of the study area is located within a high-risk flood zone, which is less than 200m away from river channels. Additionally, 28.6% of the area is situated 200-400m away, 23.1% is 400-600m away, and 15.9% and 1.1% are 800m and beyond 800m away, respectively. Notably, the river banks in this area are primarily utilized for residential, industrial, and agricultural purposes, amplifying the destructive impact of flooding. A reclassified proximity map illustrating the study area's distance to river/waterway is presented in Figure 8.

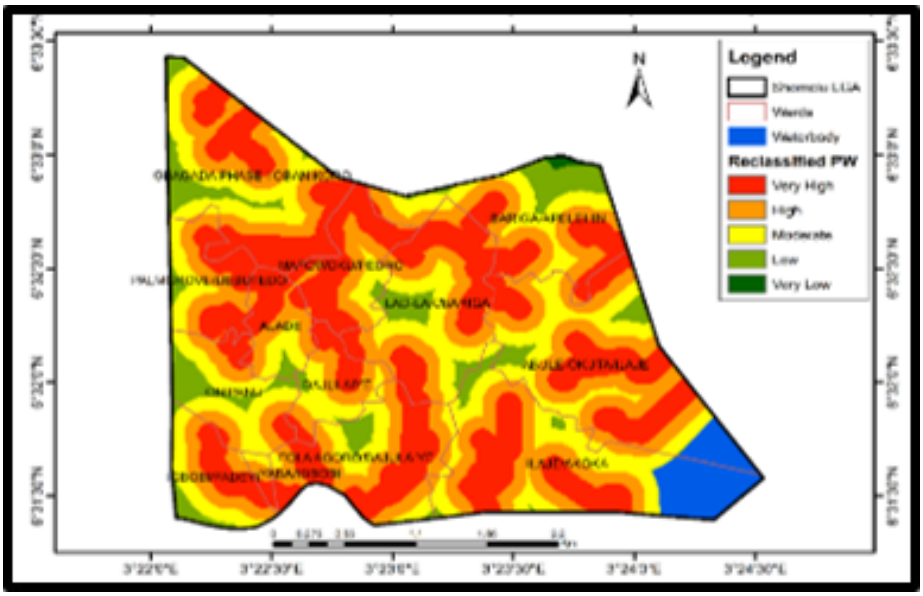


Figure 7: Reclassified Map of Proximity to Waterbody/River

Analytic Hierarchy Process of Flood Risk Factors

Pairwise comparison of the six factors influencing flood risk in the study area was carried out using Analytic Hierarchy Process (AHP) in Microsoft Excel and the results are presented in Tables 3. The AHP generates a weight for each evaluation criterion according to the decision maker's pairwise comparisons of the criteria. The higher the weight: the more important the corresponding criterion. The pairwise comparison matrix was normalized and is presented in Table 4.

Table 3: Pairwise Comparison Matrix of the Flood Risk Factors

	Rainfall	**Slope**	**Elevation**	**Proximity to river**	**Soil**	**Drainage density**
Rainfall	1	2	2	3	2	3
Slope	1/2	1	1	2	3	2
Elevation	1/2	1	1	1	2	2
Proximity to river	1/3	1/2	1	1	3	2
Soil	1/2	1/3	1/2	1/3	1	1
Drainage Density	1/3	1/2	1/2	1/2	1	1
Total	**3.2**	**5.3**	**6.0**	**7.8**	**12.0**	**11.0**

Source: Author's Analysis (2026)

The weights in Table 4 were obtained by calculating the average of each row. These are the values that were used to generate the flood vulnerability map of the study area using ArcGIS 10.8 Weighted Overlay tool. Meanwhile, the individual judgment, which never agreed perfectly with the degree of consistency achieved in the

Table 4: Normalised Pairwise Comparison Matrix for Flood Causative Factors

	Rainfall	**Slope**	**Elevation**	**Proximity to river**	**Soil**	**Drainage Density**	**Weight**
Rainfall	0.3	0.4	0.3	0.4	0.2	0.3	30.8
Slope	0.2	0.2	0.2	0.3	0.3	0.2	20.0
Elevation	0.2	0.2	0.2	0.1	0.2	0.2	16.5
Proximity to river	0.1	0.1	0.2	0.1	0.3	0.2	15.4
Soil	0.2	0.1	0.1	0.1	0.1	0.1	9.7
Drainage Density	0.1	0.1	0.1	0.1	0.1	0.1	8.7
Total	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**100.0**

Consistency Ratio CR = 0.042

ratings, was measured by using Consistency Ratio (CR), indicating the probability that the matrix rankings were randomly generated. Consistency ratio was calculated to be 0.042. This value is acceptable because it is less than 0.1 hence, the result indicates a high level of consistency. Table 4 shows that rainfall intensity had the highest weight of 30.8%, this is followed by slope with a weight of 20%, elevation had 16.5% of the total weight, soil accounted for 9.7% and drainage density had the lowest weight of 8.7%. based on this result, rainfall was found to be the major factor influencing flooding in the study area. This suggests that heavy rainfall events overwhelm the drainage capacity of the area and exceeds the soil's infiltration capacity, leading to surface runoff. Rainfall intensity amplifies flood risk, particularly since the area has a low-lying terrain. The finding corroborates that of Elsheikh *et al.* (2015) who revealed that rainfall (38.7%) was the major factor influencing flood risk in Malaysia

Extent of Flood Risk Zones

The flood prone areas of the study area were determined using the Weighted Overlay tool in the Spatial Analyst extension in ArcGIS 10.8 to perform the overlay analysis and flood susceptibility values was classified into three categories; (very high risk, moderate risk and very low risk zones) as shown in Table 5. The raster calculator in ArcGIS 10.8 was used to calculate the values for each class of flood risk zone and the final flood risk map is illustrated in Figure 9.

Table 5: Categories of Flood Risk Zones in Shomolu LGA, Lagos State

Flood Risk	Weight	Area (Ha)	%
Very High	9	511.5	34.9
Moderate	5	590.7	40.3
Very Low	1	363.5	24.8
		1465.7	100.0

Source: Author's Analysis (2026)

Table 5 revealed that very high-risk flood areas covered about 34.9% of the study area. This area was mostly located at the southeastern and the western part of the study area covering major towns like Ilejo and Akoka, also Alade ward and some part of Ijebutado were identified to be within the high flood risk zone. This suggests that the settlements within this zone are at significant risk of flooding, which could potentially impact a large number of people, infrastructure, and resources in this area. It was observed that the high flood risk areas are densely populated, this implies that a larger number of people are vulnerable to flooding, displacement, and related health risks. Flooding in these areas could also cause severe damage to critical structures such as roads, bridges, and buildings, as well as disrupting essential services and economic activities. This is not out of place as the findings of Nwilo *et al.* (2021) also revealed that high vulnerability flood risk zones accounted for 31.8% of the Adamawa catchment area, North central Nigeria.

The findings, as illustrated in Figure 9, reveal that areas with high flood risk correspond to regions of high rainfall distribution. This is due to the excessive saturation of the ground, which becomes incapable of absorbing additional

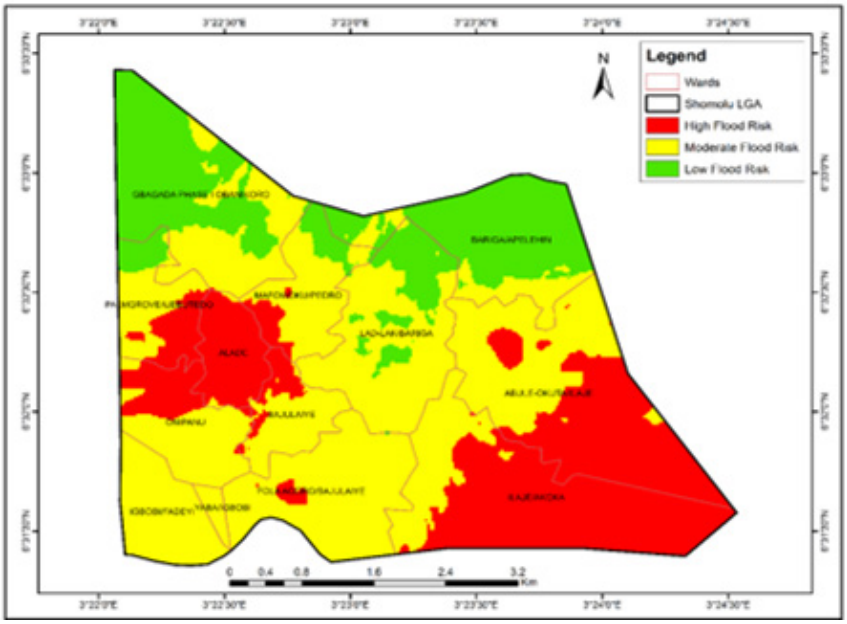


Figure 8: Flood Risk Map of Shomolu LGA

water, thereby leading to flooding. Additionally, areas with gentle slopes were observed to be more susceptible to flooding compared to elevated regions. In flat areas, water drainage is slower, allowing water to accumulate and increasing the likelihood of flooding.

The findings as illustrated in Figure 9 shows that places that have high flood risk are areas of high rainfall distribution due to the high saturation of the ground making it saturated and unable to absorb additional water thereby resulting to flooding. Areas of flatter slope were also seen to be more prone to flooding than hilly areas, as water does not drain quickly and can accumulate. Finally, areas with very high drainage density and close proximity to water bodies were also identified as high-risk zones due to storm surges, or tidal activity occurring in those areas. This finding varies with that of Bello *et al.* (2022) who analyzed flood risk along Galma dam in Kubau Local Government using geospatial technique and found that low land areas were more susceptible to flood. The finding is however is similar with that of Berezi and Nwankwoala (2023) which found three levels of flood risk zones in Bayelsa State and recorded low vulnerability to flood as 12.9%, moderate vulnerability as 59.8% and high vulnerability as 27.3% of the total area of coverage in the overlay of communities on Bayelsa flood vulnerability levels.

CONCLUSION

The study concludes that areas low-lying areas with high rainfall and along rivers channels are more prone to flooding than those at higher elevations. Although flooding is a natural disaster, humans activities contribute significantly to its occurrence because of their involvement in activities that disrupt the environment, such as encroachment of human activities on the floodplain, violation of building regulations in the areas, and the poor nature of the materials used in building houses. Therefore, based on the findings of this study, there should be improved land use planning by urban planners that prioritize residential and commercial structures due to their high vulnerability to flooding, focusing on evacuation plans, flood protection, and early warning systems. Also, government authorities should ensure the rigorous implementation of building codes in high-risk areas. Regular inspections must be conducted to verify that all structures meet the required standards, with sanctions imposed on non-compliant parties to deter future violations.

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