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Geospatial Flood Susceptibility Mapping in Ekeremor Local Government Area, Bayelsa State, Nigeria, Using Multi-Criteria Decision Analysis

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Abstract
Flooding constitutes one of the most significant environmental hazards affecting coastal communities in the Niger Delta, Nigeria, owing to the combined influence of river overflow, intense rainfall, tidal inundation, and low-lying terrain. This study assessed flood susceptibility in Ekeremor Local Government Area, Bayelsa State, using a Geographic Information System (GIS)-based Multi-Criteria Decision Analysis (MCDA) framework integrating the Analytical Hierarchy Process (AHP) and Weighted Linear Combination (WLC). Seven flood conditioning factors, namely elevation, slope, rainfall, soil, distance to river, distance to coastline, and land use/land cover (LULC), were selected based on their influence on flood occurrence. The factors were standardized and weighted using the AHP, with pairwise comparisons yielding a Consistency Ratio (CR) of 0.036, indicating acceptable consistency in the assigned criterion weights. The weighted factors were integrated using the WLC technique to generate a Flood Susceptibility Index (FSI), which was subsequently classified into five susceptibility classes: Very Low, Low, Moderate, High, and Very High. The results revealed that 544.09 km² (30.19%) of the study area falls within the Very High flood susceptibility class, while 135.86 km² (7.54%) is classified as High susceptibility. Moderate, Very Low, and Low susceptibility classes occupy 402.94 km² (22.36%), 361.74 km² (20.07%), and 357.49 km² (19.84%), respectively. Collectively, the High and Very High susceptibility classes account for 679.95 km² (37.73%) of the Local Government Area, indicating extensive exposure to flood hazards. Settlement overlay analysis further identified 156 settlements within the Very High susceptibility class, 41 settlements within the High class, 85 settlements within the Moderate class, 34 settlements within the Low class, and 73 settlements within the Very Low class. The observed spatial pattern demonstrates that flood susceptibility in Ekeremor is primarily controlled by the interaction of low elevation, gentle slopes, proximity to river channels, coastal influence, high rainfall, poorly drained soils, and land use characteristics. The generated flood susceptibility map provides a reliable spatial decision-support tool for flood risk reduction, sustainable land use planning, infrastructure development, disaster preparedness, and climate adaptation within Ekeremor Local Government Area and similar coastal environments in the Niger Delta.

Keywords: Flood Susceptibility, Geographic Information System, Analytical Hierarchy Process, Weighted Linear Combination, Multi-Criteria Decision Analysis, Ekeremor, Bayelsa State, Niger Delta

1. Introduction

Flooding is one of the most frequent and destructive natural hazards worldwide, causing extensive damage to human settlements, transportation infrastructure, agricultural lands, ecosystems, and economic activities. The increasing occurrence and severity of flood events have been attributed to the combined effects of climate variability, rapid urbanization, land use changes, and alterations in natural hydrological systems, making flood risk management an important component of sustainable environmental planning (Pham-Duc *et al*., 2020; Mojaddadi *et al*., 2020; Saleh *et al*., 2023) [7, 10, 13]. Low-lying coastal and deltaic environments are particularly susceptible because of their unique topographic characteristics, extensive drainage networks, and exposure to tidal influences (Pham-Duc *et al*., 2020) [7].

Flooding constitutes one of the most persistent environmental challenges in Nigeria, affecting both urban and rural communities across diverse ecological zones (Aderogba, 2012; Echendu, 2023) [2, 1]. Recurrent flood events have resulted in widespread destruction of residential buildings, transportation networks, public infrastructure, agricultural lands, and livelihoods while increasing the vulnerability of affected populations to poverty, disease outbreaks, and displacement

(Aderogba, 2012; Echendu, 2023) [2, 1]. Human activities such as indiscriminate waste disposal, obstruction of drainage channels, uncontrolled urban expansion, and inappropriate land use practices have further increased the frequency and impacts of flooding, particularly in rapidly developing communities where natural drainage systems have been substantially modified (Echendu, 2023) [1]. Consequently, flooding has become both an environmental and socio-economic challenge requiring integrated planning and management approaches.

The Niger Delta represents one of the regions most vulnerable to flooding in Nigeria because of its geomorphological, hydrological, and climatic characteristics (Ologunorisa and Akinbobola, 2019) [3]. The region is characterized by extensive distributary rivers, tidal creeks, wetlands, floodplains, estuaries, and mangrove ecosystems developed on predominantly low-elevation coastal terrain (Ologunorisa and Akinbobola, 2019; Eteh and Okechukwu, 2021) [3, 4]. Seasonal river discharge, high annual rainfall, and tidal fluctuations frequently combine to produce widespread inundation across settlements located within floodplain environments (Eteh and Okechukwu, 2021; Oborie and Eteh, 2023) [4, 5]. The dependence of local communities on rivers for transportation, fishing, agriculture, and commerce further increases human exposure to flood hazards, making the Niger Delta one of the most socially vulnerable regions to flooding in Nigeria (Ologunorisa and Akinbobola, 2019) [3].

Ekeremor Local Government Area, located in Bayelsa State within the central Niger Delta, experiences recurrent flooding because of its low elevation, extensive river systems, tidal influence, abundant rainfall, and poorly drained floodplain landscapes. Numerous settlements are situated adjacent to distributary channels and coastal wetlands, thereby increasing their exposure to riverine and coastal flooding. Flood events within the Local Government Area frequently disrupt transportation, damage residential buildings, reduce agricultural productivity, affect fishing activities, and compromise socio-economic development. The physical characteristics of the area therefore necessitate detailed spatial assessment of flood susceptibility to support effective flood risk management and sustainable land use planning (Eteh and Okechukwu, 2021; Oborie and Eteh, 2023) [4, 5].

Reliable identification of flood-prone areas is fundamental to disaster preparedness, infrastructure development, environmental management, and climate adaptation. Conventional field-based flood assessment methods are often expensive, time-consuming, and difficult to implement across extensive wetland environments such as the Niger Delta. Geographic Information Systems (GIS), Remote Sensing (RS), and Multi-Criteria Decision Analysis (MCDA) have consequently become widely adopted for flood susceptibility assessment because they provide efficient means of integrating multiple environmental variables within a spatial decision-support framework (Ikusemoran *et al*., 2013; Raji *et al*., 2014) [12, 11]. These techniques facilitate the analysis of topographic, hydrological, climatic, geological, and land use factors that collectively influence flood occurrence and spatial distribution.

Recent advances in earth observation technologies have substantially improved flood monitoring and susceptibility assessment. Synthetic Aperture Radar (SAR) imagery has become particularly valuable because it enables flood detection regardless of cloud cover and weather conditions, making it highly suitable for humid tropical environments (Pham-Duc *et al*., 2020; Saleh *et al*., 2023) [7, 13]. Machine learning techniques have further enhanced flood mapping by improving predictive accuracy through the integration of remotely sensed and geospatial datasets (Mojaddadi *et al*., 2020; Ighile *et al*., 2022) [10, 9]. Within Nigeria, GIS integrated with machine learning has been successfully applied to flood prediction and susceptibility assessment (Ighile *et al*., 2022) [9], while recent studies in Bayelsa State have demonstrated the effectiveness of Sentinel-1 and Sentinel-2 imagery for flood extent mapping and flood damage assessment (Bamiekumo *et al*., 2025) [8]. Other investigations within the Niger Delta have employed remote sensing and GIS for floodplain delineation, morphometric analysis, and river system assessment, further demonstrating the capability of geospatial technologies for flood studies (Eteh and Okechukwu, 2021; Oborie and Eteh, 2023; Okpobiri *et al*., 2025) [4, 5, 6].

Although machine learning approaches have demonstrated high predictive capability, their implementation often requires extensive historical flood inventories and large training datasets that are not always available for many parts of Nigeria. Geographic Information System-based Multi-Criteria Decision Analysis therefore remains one of the most practical and widely adopted approaches for flood susceptibility mapping because it effectively integrates expert knowledge with multiple flood conditioning factors (Ikusemoran *et al*., 2013; Raji *et al*., 2014) [12, 11]. Among the available MCDA techniques, the Analytical Hierarchy Process (AHP) provides a systematic framework for assigning relative importance to flood conditioning factors through pairwise comparisons while evaluating the consistency of expert judgments. When integrated with the Weighted Linear Combination (WLC) technique, AHP enables the generation of reliable flood susceptibility maps capable of supporting evidence-based environmental planning and disaster risk reduction.

Despite the increasing number of flood studies undertaken within the Niger Delta, detailed flood susceptibility assessments focusing specifically on Ekeremor Local Government Area remain limited. Existing investigations have largely emphasized floodplain mapping, flood extent extraction, morphometric analysis, machine learning applications, and regional flood monitoring rather than the integration of elevation, slope, rainfall, soil, distance to river, distance to coastline, and land use/land cover within a GIS-based Analytical Hierarchy Process framework (Eteh and Okechukwu, 2021; Oborie and Eteh, 2023; Ighile *et al*., 2022; Bamiekumo *et al*., 2025) [4, 5, 9, 8]. Consequently, comprehensive spatial information required for local-scale flood risk management and sustainable land use planning within Ekeremor remains inadequate.

This study therefore employed a Geographic Information System-based Analytical Hierarchy Process (AHP) and Weighted Linear Combination (WLC) approach to assess flood susceptibility in Ekeremor Local Government Area, Bayelsa State, Nigeria. Seven flood conditioning factors comprising elevation, slope, rainfall, soil, distance to river, distance to coastline, and land use/land cover were integrated to generate a flood susceptibility map and identify settlements exposed to different levels of flood hazard. The findings provide spatial information that can support flood mitigation planning, disaster preparedness, infrastructure development, environmental management, and climate adaptation within Ekeremor Local Government Area and other coastal environments of the Niger Delta.

2. Materials and Methods

2.1 Study Area

Ekeremor Local Government Area is located in the southwestern part of Bayelsa State, Nigeria, within the coastal Niger Delta. The Local Government Area lies approximately between latitudes 4°44′N and 5°12′N and longitudes 5°23′E and 5°58′E, covering an area of approximately 1,802 km². The area is characterized by extensive wetlands, mangrove forests, tidal creeks, distributary channels of the River Niger, and low-lying floodplains. The climate is humid tropical with high annual rainfall exceeding 2,500 mm and relatively uniform temperatures throughout the year. Fishing, farming, transportation, and oil exploration constitute the dominant economic activities. The combination of abundant rainfall, low relief, tidal influence, and dense drainage networks makes the Local Government Area highly susceptible to both riverine and coastal flooding.

2.2 Data Acquisition

Both remotely sensed and ancillary spatial datasets were employed to model flood susceptibility in Burutu Local Government Area. Seven flood conditioning factors considered in the analysis were elevation, slope, rainfall, soil, distance to rivers, distance to the coastline, and land use/land cover (LULC). Table 1 presents the datasets used in the study.

Table 1: Spatial datasets used for flood susceptibility modelling

Dataset	Source	Spatial Resolution	Purpose
Digital Elevation Model (DEM)	Shuttle Radar Topography Mission (SRTM)	30 m	Derivation of elevation and slope
Rainfall	CHIRPS Climate Data	0.05°	Rainfall distribution
Soil Map	FAO Digital Soil Database	250 m	Soil characteristics
River Network	HydroSHEDS	Vector	Distance to rivers
Coastline	OpenStreetMap	Vector	Distance to coastline
Landsat 8 OLI	USGS Earth Explorer	30 m	Land use/Land cover mapping
Administrative Boundary	Office of the Surveyor General	Vector	Extraction of study area

All spatial datasets were projected to the Universal Transverse Mercator (UTM) Zone 32N, WGS 84 coordinate system to ensure spatial consistency during analysis.

2.3 Data Preparation

All datasets were preprocessed prior to analysis. The Digital Elevation Model (DEM) was clipped to the study area boundary before deriving elevation and slope layers using the Spatial Analyst tools in ArcGIS Pro. River and coastline shapefiles were converted into Euclidean distance raster surfaces representing the distance of every location from the nearest river and coastline, respectively.
The Euclidean distance was computed using equation (1):

$$D = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \quad (1)$$

Where
(D) = Euclidean distance,
(x_1, y_1) = coordinates of a raster cell,
(x_2, y_2) = coordinates of the nearest river or coastline.

Rainfall data were resampled to match the spatial resolution of the DEM. The soil map was converted into raster format, while Landsat 8 imagery was processed through supervised classification using the Maximum Likelihood Classification algorithm to produce the land use/land cover map.

2.4 Selection of Flood Conditioning Factors

Seven flood conditioning factors were selected based on their hydrological significance and previous flood susceptibility studies. Elevation influences the direction of runoff movement and water accumulation. Low-lying areas generally experience greater flood susceptibility because runoff naturally flows towards depressions.
Slope determines runoff velocity. Gentle slopes promote water accumulation, whereas steep slopes facilitate rapid drainage. Rainfall represents the primary source of runoff generation. Higher rainfall amounts generally increase flood potential. Soil controls infiltration capacity and water retention. Poorly drained soils produce greater surface runoff than highly permeable soils.
Distance to rivers reflects the influence of river overflow. Areas closer to rivers are generally more susceptible to inundation. Distance to the coastline accounts for tidal influence and coastal flooding, particularly within the Niger Delta where storm surges and tidal backwater effects contribute to flooding. Land use/land cover influences infiltration and runoff generation. Impervious surfaces increase runoff, while vegetation enhances infiltration.

2.5 Standardization of Flood Conditioning Factors

Because the flood conditioning factors were measured using different units and value ranges, all factors were standardized to a common suitability scale before integration. Standardization was performed through raster reclassification into five susceptibility classes ranging from Very Low (1) to Very High (5).

Table 2: Standardization of the factors

Standardized Value	Flood Susceptibility
1	Very Low
2	Low
3	Moderate
4	High
5	Very High

Factors positively associated with flooding, including rainfall and poorly drained soils, received higher suitability scores as their values increased. Conversely, factors negatively associated with flooding, including elevation, slope, distance to rivers, and distance to the coastline, were assigned higher susceptibility scores at lower values because lower elevations and shorter distances to rivers and the coastline increase flood occurrence.

2.6 Analytical Hierarchy Process (AHP)

The relative importance of the seven flood conditioning factors was determined using the Analytical Hierarchy

Process (AHP) developed by Saaty (1980). The Analytical Hierarchy Process provides a systematic procedure for assigning relative weights to multiple decision criteria through pairwise comparison based on expert judgement. The flood conditioning factors considered in this study comprised elevation, slope, rainfall, soil, distance to river, distance to coastline, and land use/land cover (LULC).

Each criterion was compared with every other criterion using Saaty's nine-point preference scale, where 1 indicates equal importance, 3 indicates moderate importance, 5 indicates strong importance, 7 indicates very strong importance, and 9 indicates extreme importance. Reciprocal values were assigned whenever one criterion was considered less important than the other.

Considering the physical characteristics of Ekeremor Local Government Area, distance to river was regarded as the most influential factor because the Local Government Area is traversed by numerous distributary channels and tidal creeks that frequently overflow during the rainy season. Rainfall was considered the second most influential factor because prolonged rainfall generates substantial runoff over the low-lying floodplain. Elevation and distance to coastline were assigned the next highest importance because the predominantly low terrain and tidal influence contribute significantly to flood occurrence. Slope, soil, and land use/land cover were assigned comparatively lower importance. The pairwise comparison matrix developed for the study is presented in Table 3.

Table 3: Pairwise Comparison Matrix

Criteria	Elevation	Slope	Rainfall	Soil	Distance to River	Distance to Coastline	LULC
Elevation	1	3	1/2	3	1/4	2	3
Slope	1/3	1	1/4	2	1/5	1/2	2
Rainfall	2	4	1	4	1/2	2	4
Soil	1/3	1/2	1/4	1	1/5	1/2	2
Distance to River	4	5	2	5	1	3	5
Distance to Coastline	1/2	2	1/2	2	1/3	1	3
LULC	1/3	1/2	1/4	1/2	1/5	1/3	1

The pairwise comparison matrix was normalized by dividing each matrix element by the sum of its respective column. The normalized matrix is presented in Table 4.

Table 4: Normalized Pairwise Comparison Matrix

Criteria	Elevation	Slope	Rainfall	Soil	River	Coastline	LULC	Row Average
Elevation	0.118	0.188	0.105	0.171	0.093	0.214	0.150	0.148
Slope	0.039	0.063	0.053	0.114	0.074	0.054	0.100	0.071
Rainfall	0.236	0.250	0.211	0.229	0.185	0.214	0.200	0.218
Soil	0.039	0.031	0.053	0.057	0.074	0.054	0.100	0.058
Distance to River	0.472	0.313	0.421	0.286	0.370	0.321	0.250	0.348
Distance to Coastline	0.059	0.125	0.105	0.114	0.123	0.107	0.150	0.112
LULC	0.039	0.031	0.053	0.029	0.074	0.036	0.050	0.045

The normalized weight for each criterion was computed by averaging the values across each row. The final criterion weights are presented in Table 5.

Table 5: Final AHP Weights

Criterion	Weight	Percentage (%)	Rank
Distance to River	0.348	34.8	1
Rainfall	0.218	21.8	2
Elevation	0.148	14.8	3
Distance to Coastline	0.112	11.2	4
Slope	0.071	7.1	5
Soil	0.058	5.8	6
Land Use/Land Cover	0.045	4.5	7
Total	1.000	100.0	

The consistency of the pairwise comparisons was evaluated using the Consistency Index (CI) and Consistency Ratio (CR). And for the seven-factor model,

$$\lambda_{\{max\}} = 7.29$$

$$RI = 1.32$$

$$CR = 0.036$$

Since the calculated Consistency Ratio (0.036) is less than the acceptable threshold of 0.10, the pairwise comparisons are considered logically consistent and the derived criterion weights are suitable for flood susceptibility modelling.

2.7 Weighted Linear Combination (WLC)

The standardized flood conditioning factors were integrated using the Weighted Linear Combination (WLC) model. Each standardized raster layer was multiplied by its corresponding AHP-derived weight before summation to produce the Flood Susceptibility Index (FSI).

The Flood Susceptibility Index was calculated as:

$$FSI = (0.148E) + (0.071S) + (0.218R) + (0.058So) + (0.348DR) + (0.112DC) + (0.045L)$$

Where

FSI = Flood Susceptibility Index
E = Elevation
S = Slope
R = Rainfall
So = Soil
DR = Distance to River
DC = Distance to Coastline
L = Land Use/Land Cover

The resulting Flood Susceptibility Index raster was classified into Very Low, Low, Moderate, High, and Very High susceptibility classes using the Natural Breaks (Jenks) classification method.

2.8 Settlement Exposure Analysis

The settlement layer was overlaid on the final flood susceptibility map using the Spatial Join tool in ArcGIS Pro to determine the susceptibility class of each settlement. This procedure enabled the identification of communities located within the various flood susceptibility zones and facilitated the assessment of settlement exposure to flooding.

3. Results

3.1 Flood Susceptibility Zonation in Ekeremor Local Government Area

The integration of elevation, slope, rainfall, soil, distance to river, distance to coastline, and land use/land cover (LULC) using the Analytical Hierarchy Process (AHP) and Weighted Linear Combination (WLC) produced the flood susceptibility map for Ekeremor Local Government Area (Fig 3.1). The Flood Susceptibility Index (FSI) was classified into five categories, namely Very Low, Low, Moderate, High, and Very High susceptibility, representing increasing likelihood of flood occurrence. The spatial extent of each susceptibility class is presented in Table 1, while their spatial distribution is illustrated in Fig 1.

Table 1: Spatial Distribution of Flood Susceptibility Zones in Ekeremor LGA

Flood Susceptibility Class	Area (km²)	Percentage (%)
Very Low	361.74	20.07
Low	357.49	19.84
Moderate	402.94	22.36
High	135.86	7.54
Very High	544.09	30.19
Total	1,802.12	100.00

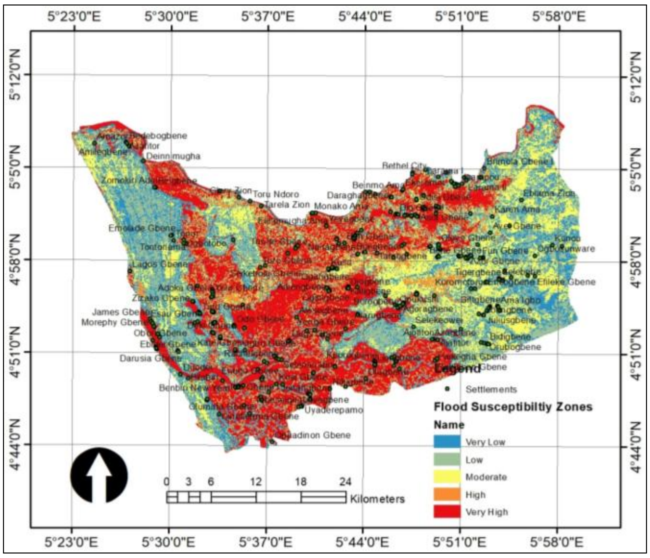

Fig 1: Flood Susceptibility Zones in Ekeremor LGA

Table 1 indicates that the Very High flood susceptibility class occupies the largest proportion of the study area, covering 544.09 km² (30.19%). The Moderate susceptibility class accounts for 402.94 km² (22.36%), while the Very Low and Low classes occupy 361.74 km² (20.07%) and 357.49 km² (19.84%), respectively. High susceptibility areas cover the smallest proportion of the Local Government Area, representing 135.86 km² (7.54%).

The spatial distribution shown in Fig 1 demonstrates that the Very High susceptibility zones are predominantly concentrated across the central and southern portions of Ekeremor Local Government Area, extending into several western communities. Moderate susceptibility areas occur as transition zones surrounding the highly susceptible regions, where as the Low and Very Low classes are more prominent toward the eastern and northwestern sections of the study area. The irregular distribution of susceptibility classes reflects the spatial variability of terrain characteristics, hydrological conditions, coastal influence, and land use patterns across the Local Government Area.

The dominance of the Very High susceptibility class indicates that flooding represents a major environmental challenge within Ekeremor. This pattern is largely attributable to the combined effects of low elevation, gentle terrain, extensive river networks, coastal influence, high annual rainfall, hydromorphic soils, and land cover characteristics that collectively favour runoff accumulation and prolonged inundation. As a coastal Local Government Area situated within the Niger Delta, Ekeremor is exposed to compound flooding arising from the interaction of river overflow, tidal backwater effects, coastal processes, and intense rainfall events. The integrated AHP-WLC model effectively captured these interacting controls by assigning relative importance to each flood conditioning factor before producing the final Flood Susceptibility Index.

The influence of elevation is evident in the concentration of high susceptibility zones within the low-lying portions of the Local Government Area. Low elevations naturally function as runoff receiving areas where surface water accumulates following prolonged rainfall. This effect is reinforced by the generally gentle slopes characteristic of the Niger Delta coastal plain, which reduce runoff velocity and delay drainage, thereby increasing both flood depth and duration.

Distance to rivers also contributes substantially to the observed spatial pattern. Large portions of Ekeremor are intersected by distributaries of the Niger River and numerous tidal creeks that frequently overflow during periods of high discharge. Settlements located adjacent to these waterways are therefore exposed to direct fluvial flooding in addition to local surface runoff accumulation. Similarly, proximity to the Atlantic coastline increases susceptibility through tidal inundation and storm surge effects that restrict river discharge during high tides, causing floodwaters to remain on the landscape for extended periods.

Rainfall further enhances flood susceptibility because Ekeremor experiences the humid tropical climate typical of the Niger Delta, characterized by abundant annual precipitation. During periods of prolonged rainfall, infiltration capacity is exceeded, generating substantial surface runoff. The predominance of poorly drained alluvial and hydromorphic soils further limits infiltration, resulting in increased ponding and slower recession of floodwaters.

Land use and land cover also influence the susceptibility pattern by modifying infiltration and runoff characteristics. Wetlands and mangrove ecosystems naturally store floodwaters; however, settlements and developed areas introduce impervious surfaces that accelerate runoff generation. Consequently, areas where human development coincides with river corridors and low-lying terrain exhibit the greatest flood susceptibility.

3.2 Settlement Exposure to Flood Susceptibility

The overlay of settlement locations on the flood susceptibility map enabled the identification of communities exposed to the various flood susceptibility classes. The distribution of settlements according to susceptibility category is presented in Table 2.

Table 2: Distribution of Settlements According to Flood Susceptibility Class

Flood Susceptibility Class	Number of Settlements
Very Low	73
Low	34
Moderate	85
High	41
Very High	156
Total	389

Table 3.2 reveals that 156 settlements, representing the largest proportion of communities within the Local Government Area, are situated within the Very High flood susceptibility zone. A further 41 settlements occur within the High susceptibility class, while 85 settlements are located in areas of Moderate susceptibility. Only 73 and 34 settlements fall within the Very Low and Low susceptibility categories, respectively.

The concentration of settlements within the Very High susceptibility class demonstrates the substantial exposure of the population to recurrent flood hazards. Many communities in Ekeremor have historically developed along rivers, creeks, and coastal waterways because these environments provide access to fishing grounds, transportation routes, agriculture, and other livelihood opportunities. Although these locations offer considerable socioeconomic advantages, they also expose settlements to repeated riverine and coastal flooding.

The settlement exposure pattern further indicates that population vulnerability is influenced not only by the physical characteristics of the environment but also by the spatial distribution of human activities. Communities located within the Very High susceptibility zones are likely to experience more frequent inundation, prolonged flood duration, disruption of transportation networks, damage to residential buildings, reduced agricultural productivity, and increased pressure on public infrastructure during major flood events.

The findings therefore demonstrate that flood risk management within Ekeremor should prioritize settlements located within the Very High susceptibility zones through improved drainage infrastructure, flood forecasting and early warning systems, ecosystem conservation, floodplain management, and climate-resilient development planning. The settlement exposure analysis also provides an important basis for emergency preparedness, evacuation planning, infrastructure investment, and sustainable land use regulation within the Local Government Area.

4. Discussion of Results

The flood susceptibility assessment demonstrates that flooding in Ekeremor Local Government Area is governed by the interaction of topographic, hydrological, climatic, coastal, and land surface characteristics. The integration of elevation, slope, rainfall, soil, distance to river, distance to coastline, and land use/land cover using the Analytical Hierarchy Process (AHP) and Weighted Linear Combination (WLC) revealed considerable spatial variability in flood susceptibility across the Local Government Area. The predominance of the Very High susceptibility class, which occupies approximately 30.19% of the study area, indicates that flooding is not confined to isolated locations but represents a widespread environmental process within the coastal Niger Delta. This pattern reflects the cumulative influence of multiple flood conditioning factors rather than the dominance of any single environmental variable.

The extensive distribution of Very High susceptibility zones is primarily associated with the physiographic characteristics of Ekeremor Local Government Area. The area forms part of the Niger Delta coastal plain, which is characterized by very low elevations and minimal topographic gradients. Such landscapes naturally function as runoff receiving environments because surface water flows from relatively higher terrain towards lower depressions where drainage is considerably slower. Consequently, floodwaters remain on the landscape for extended periods following intense rainfall or river overflow. The widespread occurrence of low-lying terrain therefore provides a physical explanation for the extensive concentration of highly susceptible areas observed across the central and southern portions of the Local Government Area.

The influence of slope further reinforces the observed susceptibility pattern. Gentle slopes dominate much of Ekeremor, resulting in reduced runoff velocity and increased surface water retention. Under these conditions, runoff generated during rainfall events is unable to drain efficiently, thereby increasing both flood depth and flood duration. The interaction between low elevation and gentle slopes therefore creates favourable conditions for widespread inundation. Areas characterized by relatively higher elevations and steeper slopes, particularly within portions of the eastern and northwestern sections of the study area, exhibited comparatively lower susceptibility because runoff is conveyed more efficiently, reducing opportunities for prolonged water accumulation.

Hydrological conditions also play a major role in controlling flood susceptibility throughout the Local Government Area. Ekeremor is traversed by numerous distributary channels of the Niger River, tidal creeks, and interconnected waterways that frequently experience elevated water levels during the rainy season. Settlements and landscapes located close to these river systems are exposed to direct fluvial flooding resulting from channel overflow. The spatial coincidence between river corridors and highly susceptible zones therefore demonstrates the importance of river proximity as a controlling factor in flood occurrence. During periods of high discharge, floodwaters readily spread across adjoining floodplains, substantially increasing inundation extent within surrounding communities.

Proximity to the Atlantic coastline further contributes to the observed flood susceptibility pattern. Unlike inland flood-prone areas where flooding is predominantly controlled by rainfall-runoff processes, coastal communities in Ekeremor experience compound flooding generated through the interaction of river overflow, tidal fluctuations, and storm surges. High tides reduce the capacity of rivers to discharge runoff into the ocean, thereby causing floodwaters to back up into distributary channels and adjoining floodplains. This interaction prolongs flood duration and increases inundation frequency in communities situated close to the coastline. The inclusion of distance to coastline as a flood conditioning factor therefore improves the representation of flood processes within coastal environments compared with conventional inland flood susceptibility models.

Rainfall serves as the principal triggering mechanism for flooding within the study area. Ekeremor experiences a humid tropical climate characterized by high annual rainfall distributed over a prolonged rainy season. Although rainfall occurs relatively uniformly across much of the Local Government Area, its hydrological response varies according to local terrain, drainage conditions, soil properties, and proximity to rivers. Consequently, rainfall interacts with other environmental factors to determine where floodwaters accumulate rather than acting independently as the sole determinant of flood occurrence.

The contribution of soil characteristics is also evident in the spatial distribution of susceptibility classes. Large portions of Ekeremor consist of hydromorphic and poorly drained alluvial soils that exhibit relatively low infiltration capacities once saturated. During prolonged rainfall events, these soils quickly reach saturation, causing additional rainfall to be converted into surface runoff rather than infiltrating into the subsurface. Reduced infiltration consequently increases both runoff generation and flood persistence, particularly within low-lying floodplain environments.

Land use and land cover further modify the hydrological response of the landscape. Wetlands and mangrove ecosystems naturally function as flood storage areas by temporarily retaining excess runoff and attenuating flood peaks. However, increasing settlement expansion, infrastructure development, and conversion of natural landscapes alter surface permeability and reduce infiltration capacity. Built-up areas generate larger runoff volumes because of impervious surfaces, while disturbance of natural wetlands reduces their ability to regulate floodwaters. The concentration of high susceptibility within developed riverine communities therefore reflects the combined influence of natural floodplain characteristics and anthropogenic modification of the landscape.

The settlement exposure analysis indicates that flood vulnerability within Ekeremor extends beyond environmental susceptibility to include significant human exposure. The finding that 156 settlements occur within the Very High flood susceptibility class demonstrates that a substantial proportion of the Local Government Area's population resides in highly flood-prone environments. This settlement pattern largely reflects the historical dependence of Niger Delta communities on rivers and creeks for transportation, fishing, agriculture, and commercial activities. Consequently, many settlements have developed directly adjacent to waterways where accessibility to water resources is maximized despite the associated flood hazard.

The concentration of communities within highly susceptible zones has important implications for disaster risk management. Recurrent flooding is likely to disrupt transportation, damage residential buildings, affect educational and healthcare facilities, reduce agricultural productivity, contaminate water supplies, and interrupt economic activities. Repeated flood events may also increase household vulnerability through the cumulative loss of assets and livelihoods, particularly in communities with limited adaptive capacity. These findings demonstrate that flood risk within Ekeremor is determined by the interaction between environmental susceptibility and the spatial distribution of settlements rather than by physical conditions alone.

Comparison with previous studies undertaken within the Niger Delta demonstrates considerable agreement regarding the dominant environmental controls of flooding. Previous investigations have consistently identified low elevation, gentle slopes, proximity to rivers, poor drainage conditions, coastal influence, and land use characteristics as major determinants of flood occurrence within deltaic environments. The present study reinforces these findings by demonstrating that the integration of these factors using a GIS-based Analytical Hierarchy Process and Weighted Linear Combination provides an effective framework for identifying flood-prone areas at the local government scale.

The flood susceptibility map generated in this study has practical significance for land use planning, infrastructure development, and disaster preparedness within Ekeremor Local Government Area. Areas classified as High and Very High susceptibility should receive priority attention during the planning of residential developments, transportation infrastructure, public facilities, and emergency response systems. Existing settlements within these highly susceptible zones require improved drainage infrastructure, flood forecasting systems, early warning mechanisms, ecosystem conservation programmes, and community-based disaster preparedness initiatives. Areas classified as Low and Very Low susceptibility provide relatively more suitable locations for future development, although detailed site-specific investigations remain necessary before project implementation.

Overall, the results demonstrate that flood susceptibility in Ekeremor Local Government Area is governed by the combined influence of terrain characteristics, river systems, coastal processes, climatic conditions, soil properties, and land use dynamics. The integration of these factors through the AHP-WLC framework provides a robust spatial decision-support tool capable of guiding sustainable land use planning, flood mitigation strategies, infrastructure investment, and climate adaptation planning within coastal communities of the Niger Delta.

5. Conclusion and Recommendations

This study assessed flood susceptibility in Ekeremor Local Government Area, Bayelsa State, using a Geographic Information System (GIS)-based Analytical Hierarchy Process (AHP) and Weighted Linear Combination (WLC) approach. Seven flood conditioning factors, namely elevation, slope, rainfall, soil, distance to river, distance to coastline, and land use/land cover, were integrated to generate a Flood Susceptibility Index and delineate areas with varying levels of flood susceptibility. The resulting susceptibility map classified the study area into Very Low, Low, Moderate, High, and Very High flood susceptibility zones. The findings revealed that the Very High susceptibility class occupies the largest proportion of the Local Government Area, accounting for 544.09 km² (30.19%), while the combined High and Very High susceptibility classes cover 679.95 km² (37.73%), indicating that more than one-third of the Local Government Area is highly susceptible to flooding.

The spatial pattern of flood susceptibility demonstrates that flooding in Ekeremor is principally controlled by the interaction of low elevation, gentle slopes, proximity to distributary river channels, coastal influence, high rainfall, poorly drained soils, and land use characteristics. These environmental conditions collectively promote runoff accumulation, prolonged water retention, and frequent inundation, particularly within the central and southern parts of the Local Government Area. The settlement overlay further revealed that 156 communities are located within the Very High flood susceptibility class, demonstrating the considerable exposure of human settlements to flood hazards. The concentration of settlements within highly susceptible environments reflects the historical dependence of riverine communities on waterways for transportation, fishing, agriculture, and commerce, while simultaneously increasing their vulnerability to recurrent flooding.

The flood susceptibility map developed in this study provides a scientifically robust spatial decision-support tool for flood risk management in Ekeremor Local Government Area. The integration of multiple flood conditioning factors through the AHP-WLC framework demonstrates the effectiveness of GIS-based Multi-Criteria Decision Analysis for identifying flood-prone areas and supporting evidence-based planning in coastal environments. The outputs of this study can support disaster preparedness, infrastructure planning, environmental management, and climate adaptation initiatives aimed at reducing future flood impacts within the Local Government Area.

Based on these findings, future residential, commercial, and public infrastructure development should be directed towards areas classified as Low and Very Low flood susceptibility wherever feasible. Proposed developments within High and Very High susceptibility zones should be preceded by detailed flood risk assessments and the implementation of appropriate engineering and environmental mitigation measures.

Communities located within the High and Very High flood susceptibility classes should be prioritized for the provision of improved drainage infrastructure, river channel maintenance, flood control structures, and regular desilting of drainage pathways to enhance runoff conveyance and reduce flood duration.

Government agencies responsible for disaster risk management should strengthen flood forecasting, early warning systems, and emergency response programmes, particularly for the 156 settlements identified within the Very High flood susceptibility class. Community-based awareness campaigns should also be intensified to improve public understanding of flood hazards, preparedness measures, and evacuation procedures.

Wetlands, mangrove forests, and other natural flood retention ecosystems should be protected and restored to enhance their capacity to attenuate floodwaters and regulate surface runoff. Uncontrolled reclamation of wetlands and indiscriminate development within floodplains should be discouraged through effective land use planning and enforcement of environmental regulations.

Flood susceptibility maps such as the one developed in this study should be incorporated into local and state physical planning policies to guide zoning decisions, infrastructure investments, and future urban expansion. Such integration will reduce exposure to flood hazards while promoting sustainable development within the Local Government Area.

Future investigations should incorporate additional hydrological variables, including drainage density, flow accumulation, groundwater conditions, tidal dynamics, and projected climate change scenarios, to further improve flood susceptibility modelling. Validation using historical flood inventories, hydraulic modelling, and high-resolution remotely sensed datasets would further enhance the predictive capability and operational applicability of future flood susceptibility assessments in coastal environments.

6. References

1. Echendu AJ. Flooding and waste disposal practices of urban residents in Nigeria. GeoHazards. 2023; 4(4):350-366. Doi: https://doi.org/10.3390/geohazards4040020
2. Aderogba KA. Substantive causes and effects of floods in South Western Nigeria and sustainable development of the cities and towns. Journal of Emerging Trends in Educational Research and Policy Studies. 2012; 3(4):551-560.
3. Ologunorisa TE, Akinbobola A. Assessment of social vulnerability to flood risk in the Niger Delta, Nigeria. In J. M. Adegoke, B. Sylla, A. Bossa, K. Ogunjobi, and J. Adounkpe (Eds.), Regional climate change series: Floods. WASCAL Publishing, 2019, 68-73. Doi: https://doi.org/10.33183/2019.rccs.p68
4. Eteh DR, Okechukwu O. Floodplain mapping and risks assessment of the Orashi River using remote sensing and GIS in the Niger Delta region, Nigeria. Journal of Geographical Research. 2021; 4(2):10-16. Doi: https://doi.org/10.30564/jgr.v4i2.3014
5. Oborie E, Eteh DR. Flood influence using GIS and remote sensing based morphometric parameters: A case study in Niger Delta region. Journal of Asian Scientific Research. 2023; 13(1):1-15.
6. Okpobiri O, Akajiaku CU, Eteh DR, Moses P. Using machine learning and GIS to monitor sandbars along the River Niger in the Niger Delta, Nigeria. International Journal of Environment and Climate Change. 2025; 15(2):182-203. Doi: https://doi.org/10.9734/ijecc/2025/v15i24721
7. Pham-Duc B, Prigent C, Aires F. Surface water monitoring within Cambodia and the Vietnamese Mekong Delta over a year, with Sentinel-1 SAR observations. Water. 2020; 12(3):793. Doi: https://doi.org/10.3390/w12030793
8. Bamiekumo P, Emmanuella O, Eteh R. Machine learning-based flood extent mapping and damage assessment in Yenagoa, Bayelsa State, using Sentinel-1 and 2 imagery (2018–2022). Choice Reviews, 2025.
9. Ighile EH, Shirakawa H, Tanikawa H. Application of GIS and machine learning to predict flood areas in Nigeria. Sustainability. 2022; 14(9):5039. Doi: https://doi.org/10.3390/su14095039
10. Mojaddadi H, Pradhan B, Nampak H, Ahmad N. Spatio-temporal analysis of flood susceptibility using integrated machine learning models. Journal of Environmental Management. 2020; 273:111595. Doi: https://doi.org/10.1016/j.jenvman.2020.111595
11. Raji SA, Adeniyi PO, Odunuga S. Multicriteria flood risk analysis of Lower Ogun River Basin. Journal of Environment and Earth Science. 2014; 14(13):112-125.
12. Ikusemoran M, Dami A, Maryah UM. GIS based assessment of flood risk and vulnerability of communities in the Benue floodplains, Adamawa State, Nigeria. Journal of Geography and Geology. 2013; 5(4):148-160. Doi: https://doi.org/10.5539/jgg.v5n4p148
13. Saleh T, Weng X, Holail S, Hao C, Xia G. DAM-Net: Global flood detection from SAR imagery using differential attention metric-based vision transformers. arXiv, 2023. Doi: https://doi.org/10.48550/arXiv.2306.00704