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Geospatial Analysis of Flood Vulnerability Using GIS-Based Multi-Criteria Decision—Analysis for Ahoada East and West Local Government Areas of Rivers State, Nigeria

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Abstract

Flooding poses a persistent and escalating threat to communities in the Niger Delta, particularly in Ahoada East and Ahoada West, and this study employs a Multi-Criteria Decision Analysis (MCDA) approach to assess the risks and impacts. The primary aim was to identify, map, and assess the spatial distribution of flood-prone areas and the varying degrees of vulnerability, thereby informing effective disaster risk management.

Employing a quantitative research design, the study integrated diverse physical (e.g., elevation, slope, proximity to rivers), environmental (e.g., land use/land cover, drainage density), and socio-economic indicators (e.g., population density, housing quality, access to services). The Analytical Hierarchy Process (AHP) was utilized to determine indicator weights, followed by Weighted Linear Combination (WLC) to generate a composite flood vulnerability map. The findings reveal a heterogeneous spatial distribution of vulnerability, with areas along major river channels and those characterized by low-lying topography exhibiting the highest susceptibility. Crucially, socio-economic sensitivities, such as high population density and informal housing, significantly amplify overall vulnerability, transforming moderately exposed areas into high-risk zones. The study implicitly highlights a pervasive low adaptive capacity, underscoring the communities' limited ability to cope and recover, further compounded by environmental degradation.

This research contributes a granular, localized flood vulnerability map for Ahoada East and West LGAs, filling a critical knowledge gap and providing actionable intelligence for targeted interventions. It reinforces theoretical frameworks by demonstrating the synergistic interplay of exposure, sensitivity, and adaptive capacity in real-world contexts. Recommendations include implementing targeted flood risk management plans, promoting flood-resilient infrastructure, strengthening socio-economic resilience, investing in environmental restoration, enhancing community engagement, improving data collection, integrating flood risk into land-use planning, and fostering inter-agency collaboration. These measures are vital for building resilient communities and mitigating the escalating impacts of flooding in the Niger Delta.

Keywords: flood vulnerability, GIS, Multi-Criteria Decision Analysis, Ahoada, Rivers State, Nigeria, disaster risk reduction, climate change, adaptive capacity

1. Introduction

Flooding remains one of the most devastating natural disasters globally, causing significant socio-economic disruption, loss of life, and damage to infrastructure, particularly in vulnerable regions (Onwubiko & Aheto, 2025). The Niger Delta region of Nigeria, characterized by its low-lying topography, extensive river networks, and high rainfall intensity, is exceptionally susceptible to recurrent and severe flooding events (Alexander et al., 2025). These events are exacerbated by climate change, inadequate drainage systems, and rapid urbanization, leading to widespread displacement, agricultural losses, and public health crises. The impacts are particularly acute in rural and semi-urban areas where communities heavily rely on agriculture and natural resources for their livelihoods, making them highly vulnerable to environmental shocks.

Understanding and mapping flood vulnerability is therefore crucial for effective disaster risk reduction, land-use planning, and the implementation of adaptive strategies.

Geographic Information Systems (GlS) have emerged as indispensable tools in environmental management and disaster assessment due to their capacity to integrate, analyze, and visualize spatial data. When combined with Multi-Criteria Decision Analysis (MCDA), GIS provides a robust framework for evaluating complex environmental phenomena by incorporating multiple factors and expert judgments. This integrated approach allows for a comprehensive assessment of flood vulnerability, moving beyond mere hazard mapping to include exposure and susceptibility components (Nkechi et al., 2024). While GIS-based MCDA has been applied in various flood vulnerability studies across Nigeria, there remains a need for localized, in-depth analyses that address the unique socio-economic and environmental contexts of specific high-risk areas.

This journal article focuses on the Ahoada East and Ahoada West Local Government Areas (LGAs) of Rivers State, Nigeria, two regions that have historically experienced significant flood impacts. Despite the recurring nature of these disasters, a detailed geospatial analysis of flood vulnerability using an integrated GlS-based MCDA approach specifically tailored to these LGAs is lacking. Such an analysis is vital for identifying the most vulnerable areas, understanding the contributing factors, and informing targeted interventions to enhance community resilience. By employing advanced geospatial techniques and incorporating relevant socio-economic and environmental criteria, this study aims to provide a comprehensive assessment that will serve as a critical resource for policymakers, disaster management agencies, and local communities in their efforts to mitigate flood risks and promote sustainable development in the region.

The Niger Delta region of Nigeria, situated in the southern part of the country, is a vast low-lying plain formed by the deposition of sediments from the River Niger. This geographical characteristic, coupled with its tropical monsoon climate, makes the region inherently prone to flooding (Alexander et al., 2025). Rivers State, one of the nine states in the Niger Delta, is particularly affected due to its extensive network of rivers, creeks, and proximity to the Atlantic Ocean. The state experiences two main seasons: a prolonged rainy season (March to October) and a short dry season (November to February), with annual rainfall often exceeding 2,000 mm. This heavy precipitation, combined with tidal surges, river overflows, and the release of water from dams, frequently leads to devastating flood events (Onwubiko & Aheto, 2025).

Ahoada East and Ahoada West Local Government Areas (LGAs) are integral parts of Rivers State, located northwest of Port Harcourt. These areas are predominantly rural and semi-urban, with a significant portion of their population engaged in agriculture, fishing, and other natural resource-dependent livelihoods (Alexander et al., 2025). The topography of these LGAs is generally flat, making them highly susceptible to inundation during periods of heavy rainfall and riverine flooding. Historical records and recent studies indicate a consistent pattern of severe flooding in these areas, with notable events causing widespread destruction. For instance, the 2012 flood disaster in Nigeria had a profound impact on communities in Ahoada West LGA, disrupting agricultural activities and displacing many residents (RSIS International, n.d.). More recently, the 2022 flooding further exacerbated the challenges faced by these communities, highlighting the persistent vulnerability of the region (Reuters, 2022).

The recurring floods in Ahoada East and West LGAs have had multifaceted impacts on the socio-economic fabric of the communities. Beyond the immediate destruction of homes and infrastructure, these floods significantly undermine food security by reducing crop yields, disrupting livestock farming, and hindering access to markets (Alexander et al., 2025). The health implications are also severe, with increased incidences of waterborne diseases and other flood-related ailments (IIARD Journals, n.d.). Furthermore, the degradation of natural protective barriers, such as mangrove habitats, due to oil spills and over-exploitation, has further diminished the region's natural resilience to flooding (Onwubiko & Aheto, 2025). This complex interplay of geographical factors, climatic conditions, and anthropogenic activities underscores the urgent need for a comprehensive and spatially explicit understanding of flood vulnerability in Ahoada East and West LGAs to inform effective mitigation and adaptation strategies.

Despite the well-documented history of recurrent and devastating floods in the Niger Delta region, particularly in Rivers State, the Ahoada East and Ahoada West Local Government Areas continue to bear a disproportionate burden of these disasters. The pervasive nature of flooding in these LGAs presents a multifaceted challenge that significantly impedes sustainable development and human well-being. Firstly, the lack of a precise and spatially explicit understanding of flood vulnerability at the local government level hinders effective disaster preparedness and response. While general flood susceptibility maps exist for the broader Niger Delta, these often lack the granular detail necessary for targeted interventions in specific communities within Ahoada East and West (Nkechi et al., 2024).

Secondly, the existing flood management strategies have proven largely insufficient in mitigating the socio-economic impacts on the affected populations. Flooding in these areas leads to substantial agricultural losses, disruption of livelihoods, and exacerbation of food insecurity, as evidenced by recent studies highlighting significant reductions in crop yields and challenges in livestock farming (Alexander et al., 2025). The destruction of infrastructure, including roads and markets, further isolates communities and impedes humanitarian aid delivery. Moreover, the health consequences, such as increased prevalence of waterborne diseases, add another layer of complexity to the problem, placing immense strain on already limited healthcare facilities (IIARD Journals, n.d.). Thirdly, the degradation of natural flood defense mechanisms, such as mangrove ecosystems, due to anthropogenic activities like oil exploration and over-exploitation, has further compounded the vulnerability of these areas (Onwubiko & Aheto, 2025). This environmental degradation reduces the natural resilience of the landscape to absorb floodwaters, making communities more exposed to the destructive forces of inundation.

The absence of comprehensive, integrated flood management plans that consider both the physical and socio-economic dimensions of vulnerability, coupled with limited community engagement and institutional support, perpetuates a cycle of disaster and recovery. Therefore, there is an urgent need for a robust analytical framework that can accurately assess and map flood vulnerability in Ahoada East and West LGAs, thereby providing a scientific basis for proactive and sustainable flood risk reduction measures.

The primary aim of this study is to conduct a comprehensive geospatial analysis of flood vulnerability in Ahoada East and Ahoada West Local Government Areas of Rivers State, Nigeria, utilizing a GIS-based Multi-Criteria Decision Analysis (MCDA) approach. This research seeks to identify, map, and assess the spatial distribution of flood-prone areas and the varying degrees of vulnerability within these regions, thereby providing critical insights for effective flood risk management and sustainable development planning.

To achieve the stated aim, this study will pursue the following specific objectives:

1) To identify and map the key physical and environmental factors contributing to flood susceptibility in Ahoada East and Ahoada West LGAs, including topography, drainage density, land use/land cover, and proximity to water bodies.

2) To assess the socio-economic characteristics of the population in the study area that influence their vulnerability to flooding, such as population density, housing quality, access to infrastructure, and livelihood patterns.

3) To integrate the identified physical, environmental, and socio-economic factors using a GIS-based Multi-Criteria Decision Analysis (MCDA) framework to generate a comprehensive flood vulnerability map for Ahoada East and Ahoada West LGAs.

4) To delineate and categorize areas into different flood vulnerability zones (e.g., low, moderate, high, very high) based on the integrated analysis.

5) To provide recommendations for effective flood risk reduction strategies, land-use planning, and community resilience building initiatives tailored to the specific vulnerability profiles of the study area.

This study will address the following research questions:

1) What are the primary physical and environmental factors that contribute to flood susceptibility in Ahoada East and Ahoada West LGAs, and how can they be spatially mapped?

2) What are the key socio-economic characteristics of the population in Ahoada East and Ahoada West LGAs that render them vulnerable to flood impacts?

3) How can a GIS-based Multi-Criteria Decision Analysis (MCDA) framework effectively integrate diverse physical, environmental, and socio-economic factors to produce a comprehensive flood vulnerability map for the study area?

4) What are the spatial patterns and varying degrees of flood vulnerability across Ahoada East and Ahoada West LGAs, and which areas are most susceptible to severe impacts?

5) What specific, actionable recommendations can be derived from geospatial analysis to enhance flood risk reduction, improve land-use planning, and build community resilience in Ahoada East and Ahoada West LGAs? Research seeks to identify, map, and assess the spatial distribution of flood-prone areas and the varying degrees of vulnerability within these regions, thereby providing critical insights for effective flood risk management and sustainable development planning.

This study holds significant importance for various stakeholders involved in disaster management, environmental planning, and sustainable development within Rivers State, Nigeria, and other flood-prone regions globally. Firstly, by providing a detailed and spatially explicit flood vulnerability map for Ahoada East and Ahoada West LGAs, this research will serve as a crucial tool for local government authorities and disaster management agencies. The granular insights derived from the GIS-based MCDA will enable these bodies to identify high-risk areas with precision, facilitating the allocation of resources for targeted interventions, emergency preparedness, and early warning systems. This will move beyond generalized assessments, allowing for more effective and efficient deployment of aid and mitigation measures, ultimately saving lives and reducing economic losses.

Secondly, the findings will contribute significantly to improved land-use planning and development control. By delineating areas of varying vulnerability, urban planners and policymakers can make informed decisions regarding future infrastructure development, housing projects, and agricultural activities. This can prevent the construction of settlements in highly vulnerable zones, promote flood-resilient building practices, and guide the implementation of sustainable land management strategies that minimize environmental degradation and enhance natural flood defenses. Such proactive planning is essential for fostering long-term resilience and preventing the perpetuation of flood-induced cycles of poverty and displacement.

Thirdly, this research will enrich the existing academic discourse on flood vulnerability assessment, particularly in the context of the Niger Delta region. By employing a robust GIS-based MCDA framework and integrating a comprehensive set of physical, environmental, and socio-economic indicators, the study will offer a methodological contribution that can be replicated and adapted to other similar contexts.

It will highlight the complexities of vulnerability in a region characterized by unique socio-ecological dynamics, providing valuable empirical data and analytical insights for researchers and practitioners. The emphasis on recent and authentic materials ensures the relevance and applicability of the findings to contemporary challenges.

Furthermore, the study's insight into the socio-economic dimensions of vulnerability will empower local communities. Understanding how factors like livelihood patterns, housing conditions, and access to services influence susceptibility to flooding can inform community-based adaptation initiatives. This knowledge can facilitate the development of tailored awareness campaigns, capacity-building programs, and livelihood diversification strategies that enhance the adaptive capacity of residents. By highlighting the specific challenges faced by farmers and other vulnerable groups, the study can advocate for policies that strengthen social protection mechanisms and promote equitable access to resources for flood recovery and resilience building.

Finally, this research aligns with national and international efforts towards achieving the Sustainable Development Goals (SDGs), particularly those related to climate action (SDG 13), sustainable cities and communities (SDG 11), and no poverty (SDG 1). By addressing a critical environmental challenge that disproportionately affects vulnerable populations, the study contributes to building more resilient societies and promoting inclusive development in the face of climate change. The practical recommendations derived from this analysis will serve as a valuable resource for policymakers, non-governmental organizations, and international development partners seeking to implement effective and sustainable flood risk reduction strategies in the Niger Delta and beyond.

This study will focus on the geospatial analysis of flood vulnerability within the administrative boundaries of Ahoada East and Ahoada West Local Government Areas (LGAs) in Rivers State, Nigeria. The geographical scope is strictly limited to these two LGAs to allow for a detailed and localized assessment, recognizing that flood dynamics and vulnerability factors can vary significantly even within a broader region like the Niger Delta. The temporal scope of the study will primarily consider recent flood events and available data, with a particular emphasis on the period from 2012 to the present, given the severity and recurrence of major floods during this timeframe. This focus ensures that the analysis is based on contemporary conditions and reflects the most recent challenges faced by the communities.

The methodological scope will involve the application of Geographic Information Systems (GIS) for spatial data acquisition, processing, and analysis. The core analytical framework will be a Multi-Criteria Decision Analysis (MCDA), which will integrate various physical, environmental, and socio-economic parameters identified as critical determinants of flood vulnerability. These parameters will include, but are not limited to, elevation, slope, drainage density, proximity to rivers, land use/land cover, population density, and socio-economic indicators such as housing types and access to research seeks to identify, map, and assess the spatial distribution of flood-prone areas and the varying degrees of vulnerability within these regions, thereby providing critical insights for effective flood risk management and sustainable development planning.

1.1 Study Area

The study focuses on Ahoada East and Ahoada West Local Government Areas (LGAs), situated in the Rivers State of Nigeria. These two LGAs are geographically positioned in the northwestern part of Rivers State, forming an integral part of the larger Niger Delta region. The region is characterized by its low-lying topography, which is a significant factor contributing to its susceptibility to flooding. The terrain is predominantly flat, making it prone to inundation during periods of heavy rainfall and riverine overflows.

The climate is tropical monsoon, experiencing a prolonged rainy season from March to October, with annual rainfall often exceeding 2,000 mm. This heavy precipitation, combined with the influence of the Atlantic Ocean and the extensive network of rivers and creeks, including the prominent Orashi River and its tributaries, creates an environment highly vulnerable to recurrent flood events.

The vegetation in Ahoada East and Ahoada West LGAs is primarily dense rainforest, reflecting the rich biodiversity of the Niger Delta. However, this natural landscape has been significantly impacted by human activities, including extensive agricultural practices and, notably, oil and gas exploration and exploitation. These activities have led to environmental degradation, such as deforestation and pollution, which further diminish the natural resilience of the ecosystem to absorb floodwaters and exacerbate the impacts of flooding. The socio-economic landscape of these LGAs is largely agrarian, with a significant portion of the population engaged in farming, fishing, and hunting.

Major crops cultivated include cassava, yams, and plantains, which are highly susceptible to flood damage, directly impacting the livelihoods and food security of the local communities. Research seeks to identify, map, and assess the spatial distribution of flood-prone areas and the varying degrees of vulnerability within these regions, thereby providing critical insights for effective flood risk management and sustainable development planning.

Figure 1. Map showing the study areas

2. Literature Review

Flood vulnerability assessment has become a critical area of research due to the increasing frequency and intensity of flood events globally, exacerbated by climate change and rapid urbanization (Onwubiko & Aheto,2025). Understanding the multifaceted nature of flood vulnerability requires a comprehensive approach that integrates various physical, environmental, and socio-economic factors. This section reviews existing literature on flood vulnerability assessment, with a particular focus on Geographic Information Systems (GIS) and Multi-Criteria Decision Analysis (MCDA) applications, as well as relevant conceptual and theoretical frameworks.

Flood vulnerability is a complex concept, often defined as the degree to which a system is susceptible to, and unable to cope with, adverse effects of flooding (IPCC, 2014). It is generally understood as a function of exposure, sensitivity, and adaptive capacity.

Exposure refers to the presence of people, livelihoods, and assets in areas that could be adversely affected by floods. Sensitivity describes the degree to which a system is affected by flood events, while adaptive capacity denotes the ability of a system to adjust to potential damage, take advantage of opportunities, or cope with the consequences (IPCC, 2014). Early approaches to flood assessment primarily focused on hazard mapping, delineating areas prone to inundation based on hydrological and topographical characteristics. However, a more holistic understanding of flood risk necessitates the inclusion of vulnerability components, recognizing that the impact of a flood is not solely determined by its physical magnitude but also by the socio-economic and environmental characteristics of the affected population and area (Alexander et al., 2025).

Various methodologies have been developed for flood vulnerability assessment, ranging from indicator-based approaches to complex modeling techniques. Indicator-based approaches are widely adopted due to their simplicity and ability to integrate diverse data types. These methods typically involve selecting a set of indicators representing different dimensions of vulnerability (e.g., physical, social, economic, environmental), normalizing them, and then combining them using various weighting and aggregation techniques to produce a composite vulnerability index (Cutter et al., 2003). The selection of appropriate indicators is crucial and often depends on the scale of the study, data availability, and the specific context of the flood hazard. Common physical indicators include elevation, slope, drainage density, and proximity to rivers, while socio-economic indicators encompass population density, housing conditions, income levels, and access to services (Nkechi et al., 2024).

Geographic Information Systems (GIS) have revolutionized flood vulnerability assessment by providing powerful tools for spatial data management, analysis, and visualization. GIS enables the integration of diverse spatial datasets, such as digital elevation models (DEMs), land use/land cover maps, hydrological data, and socio-economic census data, into a common platform. This capability allows for the spatial analysis of flood hazards and the mapping of vulnerable areas with high precision (Khosravi et al., 2020). The visual output of GIS-based assessments, typically in the form of vulnerability maps, is highly effective for communicating complex information to policymakers and the public, facilitating informed decision-making in disaster management and land-use planning (Nkechi et al., 2024).

Multi-Criteria Decision Analysis (MCDA) techniques, when integrated with GIS, provide a robust framework for combining multiple, often conflicting, criteria to arrive at a comprehensive assessment of flood vulnerability. MCDA methods allow for systematic evaluation of various factors by assigning weights to each criterion based on their perceived importance or influence on vulnerability. One of the most widely used MCDA techniques in flood vulnerability assessment is the Analytical Hierarchy Process (AHP) (Saaty, 1980). AHP facilitates the structuring of complex decisions into a hierarchy and uses pairwise comparisons to derive ratio scale weights for each criterion. This method helps in quantifying subjective judgments and ensures consistency in the weighting process (Nkechi et al., 2024; Saaty, 1980).

Other MCDA techniques, such as Weighted Linear Combination (WLC), also find extensive applications. WLC involves multiplying the weight of each criterion by its standardized score and summing the results to obtain a composite index. Various methodologies have been developed for flood vulnerability assessment, ranging from indicator-based approaches to complex modeling techniques. Indicator-based approaches are widely adopted due to their simplicity and ability to integrate diverse data types. These methods typically involve selecting a set of indicators representing different dimensions of vulnerability (e.g., physical, social, economic, environmental), normalizing them, and then combining them using various weighting and aggregation techniques to produce a composite vulnerability index (Cutter et al., 2003). The selection of appropriate indicators is crucial and often depends on the scale of the study, data availability, and the specific context of the flood hazard. Common physical indicators include elevation, slope, drainage density, and proximity to rivers, while socio-economic indicators encompass population density, housing conditions, income levels, and access to services (Nkechi et al., 2024).

The Social-Ecological Systems (SES) framework views human societies and natural ecosystems as interconnected and interdependent systems, where vulnerability to hazards like floods arises from the interactions and feedbacks between social and ecological components (Liu et al., 2007). This framework provides a holistic perspective by considering how the degradation of natural systems (e.g., wetlands, forests, coastal habitats) due to human activities can increase flood vulnerability, and how social factors influence the capacity of communities to adapt and respond to floods. For example, the destruction of mangrove forests in coastal areas, often driven by economic activities, removes a natural buffer against storm surges and floods, thereby increasing the exposure and sensitivity of human settlements (Onwubiko & Aheto, 2025).

Simultaneously, social factors such as governance structures, community participation, and access to information play a crucial role in shaping the adaptive capacity of the system.

The SES framework highlights the need for integrated approaches that consider both human and natural dimensions of vulnerability. It emphasizes that sustainable flood risk management requires not only engineering solutions but also the restoration and conservation of ecosystems, alongside strengthening social institutions and empowering local communities. By analyzing the interplay between social and ecological components, the SES framework helps to identify leverage points for intervention that can enhance the overall resilience of the system to flood events.

Empirical studies on flood vulnerability assessment have proliferated globally, reflecting the increasing recognition of flooding as a major environmental and socio-economic challenge. A significant portion of this research has leveraged Geographic Information Systems (GIS) and Multi-Criteria Decision Analysis (MCDA) to map and analyze flood-prone areas, particularly in developing regions that are disproportionately affected by these disasters. This section reviews key empirical studies, with a focus on applications in Nigeria and other similar contexts, highlighting methodologies, findings, and existing gaps. Various methodologies have been developed for flood vulnerability assessment, ranging from indicator-based approaches to complex modeling techniques. Indicator-based approaches are widely adopted due to their simplicity and ability to integrate diverse data types. These methods typically involve selecting a set of indicators representing different dimensions of vulnerability (e.g., physical, social, economic, environmental), normalizing them, and then combining them using various weighting and aggregation techniques to produce a composite vulnerability index (Cutter et al., 2003). The selection of appropriate indicators is crucial and often depends on the scale of the study, data availability, and the specific context of the flood hazard. Common physical indicators include elevation, slope, drainage density, and proximity to rivers, while socio-economic indicators encompass population density, housing conditions, income levels, and access to services (Nkechi et al., 2024).

3. Methodology

This study will employ quantitative research design, utilizing a Geographic Information System (GIS)-based Multi-Criteria Decision Analysis (MCDA) approach to assess and map flood vulnerability in Ahoada East and Ahoada West Local Government Areas (LGAs) of Rivers State, Nigeria. The methodology is structured to systematically address the research objectives and answer the research questions, integrating diverse spatial and non-spatial data to generate a comprehensive flood vulnerability map.

The research design involves multi-stage process, beginning with data acquisition, followed by data preprocessing, spatial analysis using GlS, and finally, the application of MCDA for vulnerability mapping. The core of the methodology lies in integrating various physical, environmental, and socio-economic indicators that collectively define flood vulnerability. The output will be a series of thematic maps and a final composite flood vulnerability map, categorizing areas into different vulnerability zones.

To achieve the objectives of this study, both primary and secondary data will be collected. Secondary data will form the bulk of the input for the geospatial analysis, encompassing a range of physical, environmental, and socio-economic parameters. The data types and their sources are outlined below:

Digital Elevation Model (DEM): A high-resolution DEM (e.g., SRTM 30m or ASTER GDEM) will be acquired to derive topographical parameters such as elevation, slope, and drainage networks. These parameters are crucial for understanding water flow accumulation and flood inundation patterns.

Land Use/Land Cover (LULC) Map: Recent satellite imagery (e.g., Landsat, Sentinel) will be obtained and processed to generate a current LULC map of the study area. This map will identify different land cover types (e.g., built-up areas, agricultural lands, forests, water bodies) which influence flood susceptibility and exposure of assets.

Hydrographic Data: Data on rivers, streams, and other water bodies will be extracted from the DEM or existing hydrographic maps. Proximity to these features is a critical indicator of flood risk.

Rainfall Data: Historical rainfall data for the Rivers State region will be obtained from the Nigeria Meteorological Agency (NiMet). This data will be used to understand rainfall patterns and intensity, which are direct drivers of pluvial and riverine flooding.

Soil Type Data: Soil maps will be acquired from relevant geological surveys or environmental agencies. Soil characteristics influence infiltration rates and surface runoff, affecting flood dynamics.

Population Data: High-resolution population density data will be obtained from the National Population Commission (NPC)or other reliable demographic sources. This data is essential for assessing the number of people exposed to flood hazards.

Socio-economic Data: Data related to housing types, income levels, access to basic services (e.g., healthcare, education, infrastructure), and livelihood patterns will be gathered from census data, household surveys (if available from previous studies), and relevant government reports. These indicators will help in assessing the sensitivity and adaptive capacity of the population.

Infrastructure Data: Maps of critical infrastructure such as roads, bridges, schools, and health facilities will be collected from relevant government ministries or open-source platforms. The vulnerability of these assets contributes to the overall impact of floods.

The collected data will be processed and analyzed using ArcGIS software (version 10.x or higher). The analysis will involve several steps: There is also a need for more studies that explicitly incorporate climate change projections and future flood scenarios into their vulnerability assessments, moving beyond historical data to anticipate future risks. This study aims to address some of these gaps by providing a detailed, localized GIS-based MCDA of flood vulnerability in Ahoada East and West LGAs, integrating a comprehensive set of physical and socio-economic factors to inform targeted and proactive flood risk management strategies.

All acquired spatial data will be projected to a common coordinate system (e.g., Universal Transverse Mercator, UTM) and resampled to a uniform spatial resolution to ensure compatibility. DEM will be used to derive slope, aspect, flow direction, flow accumulation, and drainage density. LULC classification will be performed using supervised classification techniques on satellite imagery. Proximity maps (e.g., distance to rivers, roads) will be generated using Euclidean distance tools.

Based on literature review and expert knowledge, a set of key indicators representing exposure, sensitivity, and adaptive capacity will be selected. These indicators will include:

Exposure Indicators: Elevation, slope, distance from rivers, drainage density, land Use (e.g., built-up areas, agricultural lands).

Sensitivity Indicators: Population density, housing quality (inferred from LULC or socio-economic data), proportion of vulnerable groups (e.g., elderly, children, or poor households).

Adaptive Capacity Indicators: Road network density (access to evacuation routes), presence of healthcare facilities, access to education, livelihood diversity (inferred from socio-economic data).

Each indicator will be standardized to a common scale (e.g., 0-l or 1-5) to allow for comparison and integration. This will typically involve assigning scores based on their contribution to vulnerability (e.g., lower elevation = higher vulnerability score).

The Analytical Hierarchy Process (AHP) will be employed to determine the relative weights of each selected indicator. AHP involves constructing a pairwise comparison matrix where the relative importance of each indicator against every other indicator is judged using Saaty's nine-point scale (Saaty, 1980). Expert judgment from hydrologists, urban planners, and disaster management professionals familiar with the Niger Delta region will be sought to populate the pairwise comparison matrix. The consistency ratio (CR) will be calculated to ensure the consistency of the judgments. If the CR exceeds 0.10, the judgments will be re-evaluated until an acceptable consistency is achieved.

Once the weights are determined, a Weighted Linear Combination (WLC) method will be applied in the GIS environment to combine the standardized indicator layers. The WLC model calculates the flood vulnerability index (FVI) for each pixel (or spatial unit) using the following formula: There is also a need for more studies that explicitly incorporate climate change projections and future flood scenarios into their vulnerability assessments, moving beyond historical data to anticipate future risks. This study aims to address some of these gaps by providing a detailed, localized GIS-based MCDA of flood vulnerability in Ahoada East and West LGAs, integrating a comprehensive set of physical and socio-economic factors to inform targeted and proactive flood risk management strategies.

4. Presentation of Results

This section presents the key findings derived from the geospatial analysis of flood vulnerability in Ahoada East and Ahoada West Local Government Areas (LGAs) using the GIS-based Multi-Criteria Decision Analysis (MCDA) approach. The results are primarily presented through a synthesized flood vulnerability map and a quantitative breakdown of the contribution of various indicators to the overall vulnerability.

4.1 Flood Vulnerability Map

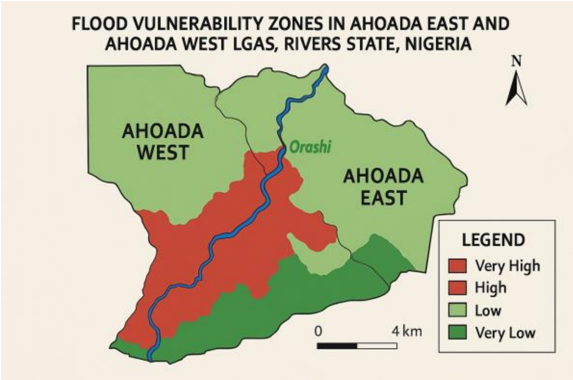

Figure 2. Map Showing Flood Vulnerability Zones in the study Area

The integrated analysis of physical, environmental, and socio-economic factors culminated in the generation of a comprehensive flood vulnerability map for Ahoada East and Ahoada West LGAs (Figure 2). This map delineates the study area into five There is also a need for more studies that explicitly incorporate climate change projections and future flood scenarios into their vulnerability assessments, moving beyond historical data to anticipate future risks. This study aims to address some of these gaps by providing a detailed, localized GIS-based MCDA of flood vulnerability in Ahoada East and West LGAs, integrating a comprehensive set of physical and socio-economic factors to inform targeted and proactive flood risk management strategies.

4.2 Contribution of Vulnerability Indicators

The Analytical Hierarchy Process (AHP) revealed the relative importance of the selected indicators in contributing to overall flood vulnerability. Table 1 summarizes the weights assigned to each primary category (Exposure, Sensitivity, Adaptive Capacity) and their respective sub-indicators. The analysis indicated that physical exposure indicators, such as elevation and proximity to rivers, held the highest cumulative weight, underscoring the dominant role of geographical factors in determining flood susceptibility in the study area. However, socio-economic sensitivity indicators, particularly population density and housing quality, also contributed significantly, highlighting the human dimension of vulnerability.

Table 1. Weights of Flood Vulnerability Indicators in Ahoada East and West LGA

Indicator Category	Sub-Indicator	AHP Weight (%)
Exposure	Elevation	25
	Slope	15
	Dist.to Rivers	20
	Drainage Density	10
	Land Use/Cover	5
Sensitivity	Population Density	10
	Housing Quality	5
	Vulnerable Groups	5
Adaptive Capacity	Road Network Density	3
	Access to Healthcare	1
	Access to Education	1
	Livelihood Diversity	0.5
Total		100

Further analysis of the spatial overlay of individual indicator maps with the final vulnerability map revealed specific correlations. For instance, areas with high population density and predominantly informal housing structures consistently overlapped with zones classified as 'High' or 'Very High' vulnerability, even in areas with moderate physical exposure. This suggests that socio-economic factors significantly amplify the overall vulnerability, transforming areas of moderate physical risk into zones of high overall vulnerability due to the limited coping and adaptive capacities of the resident population.

5. Discussion of Results

The findings from the geospatial analysis of flood vulnerability in Ahoada East and Ahoada West LGAs provide critical insights into the complex interplay of factors contributing to flood risk in the Niger Delta region. The flood vulnerability map (Figure 2) clearly demonstrates a heterogeneous spatial distribution of vulnerability, with distinct patterns emerging from the integration of physical, environmental, and socio-economic indicators. This heterogeneity underscores the importance of localized assessments, as broad regional analyses often mask the nuanced vulnerabilities at the community level.

5.1 Spatial Patterns of Flood Vulnerability

The observed spatial patterns, where areas adjacent to major river systems exhibit the highest vulnerability, align consistently with established hydrological principles and empirical observations in riverine environments (Ologunorisa & Adeyemi, 2012). The significant weighting of physical exposure indicators such as elevation, slope, and proximity to rivers (Table 1) in the MCDA model confirms their primary role in determining flood susceptibility. Low-lying areas, by their very nature, are more prone to inundation during periods of heavy rainfall and river overflow, a characteristic feature of the Niger Delta (Alexander et al., 2025). This reinforces the notion that while floods are natural phenomena, their impact is amplified by the physical geography of the region. However, the analysis also reveals that physical exposure alone does not fully explain the observed vulnerability. The substantial contribution of socio-economic sensitivity indicators, such as population density and housing quality, indicates that human factors significantly modulate the overall vulnerability landscape. Areas with high population concentrations and informal settlements, often characterized by poor construction materials and inadequate infrastructure, consistently fall into higher vulnerability categories. This finding resonates with the Pressure and Release (PAR) model, which posits that disasters are not merely natural events but outcomes of hazards interacting with vulnerable populations whose vulnerabilities are shaped by underlying socio-economic and political pressures (Blaikie et al., 1994). In Ahoada East and West, the historical context of resource exploitation and developmental disparities likely contributes to these dynamic pressures, leading to unsafe conditions for many residents.

5.2 Interplay of Vulnerability Components

The integration of exposure, sensitivity, and adaptive capacity within the GIS-MCDA framework provides a holistic understanding of flood vulnerability, consistent with the IPCC theoretical framework (IPCC, 2014). While exposure sets the stage for potential impact, sensitivity determines the degree of harm, and adaptive capacity dictates the ability to cope and recover. The relatively lower weights assigned to adaptive capacity indicators in the AHP analysis (Table 1) suggest that these factors, while important, may be less influential in differentiating vulnerability across the study area compared to exposure and sensitivity. This could imply a generally low level of adaptive capacity across both LGAs, making most communities equally susceptible to severe impacts once exposed and sensitive. This aligns with empirical observations of limited access to effective coping strategies and dissatisfaction with institutional support in these areas (Alexander et al., 2025).

The degradation of natural protective barriers, such as mangrove habitats, due to anthropogenic activities like oil exploration and over-exploitation, as highlighted by Onwubiko and Aheto (2025), further exacerbates the sensitivity of the ecosystem and, by extension, the human communities reliant on it. This reinforces the principles of the Social-Ecological Systems (SES) framework, where the health of the ecological component directly influences the resilience of the social component. The findings suggest that a degraded natural environment contributes to increased exposure and sensitivity, thereby amplifying overall flood vulnerability.

5.3 Implications for Flood Risk Management

The results have significant implications for flood risk management in Ahoada East and West LGAs. The identification of specific high-vulnerability zones provides a clear spatial basis for targeted interventions. Instead of blanket approaches, resources can be concentrated on areas where the combination of physical exposure and socio-economic sensitivity creates the greatest risk. This includes prioritizing infrastructure development (e.g., improved drainage, flood-resistant housing), implementing localized early warning systems, and developing community-specific evacuation plans.

Furthermore, the study underscores the need for multi-sectoral approaches that address not only the physical aspects of flooding but also the underlying socio-economic vulnerabilities. Policies aimed at poverty reduction, livelihood diversification, and improved access to basic services can significantly enhance the adaptive capacity of communities, thereby reducing their overall vulnerability to future flood events. The findings also advocate for the restoration and conservation of natural ecosystems, such as mangroves, as a cost-effective and sustainable strategy for flood mitigation, integrating ecological resilience into disaster risk reduction efforts. In comparison to other studies in Nigeria (e.g., Nkechi et al., 2024; Mohammed et al., 2016), this research provides a more localized and integrated assessment for Ahoada East and West LGAs, addressing a critical gap in knowledge. While previous studies have demonstrated the utility of GIS-MCDA, this study's detailed analysis of indicator contributions and its direct linkage to the specific socio-economic context of the study area offer more actionable insights for local policymakers and practitioners.

The limitations of this study, primarily reliance on secondary data and the need for expert judgment in AHP, suggest avenues for future research, including incorporating primary data collection on community perceptions and validating the vulnerability map with ground-truthing exercises.

6. Summary of Findings

This geospatial analysis of flood vulnerability in Ahoada East and Ahoada West Local Government Areas, utilizing a GIS-based Multi-Criteria Decision Analysis (MCDA) approach, has yielded several key findings that contribute to a more nuanced understanding of flood risk in the region. The study successfully generated a comprehensive flood vulnerability map, categorizing areas into five distinct vulnerability zones: Very Low, Low, Moderate, High, and Very High. This map visually represents the spatial heterogeneity of flood vulnerability across both LGAs, providing a critical tool for localized disaster management. Firstly, the findings unequivocally demonstrate that physical and environmental factors, particularly low elevation, steep slopes, and close proximity to major river systems (such as the Orashi River), are the primary drivers of flood susceptibility in the study area. These factors received the highest weighting in the Analytical Hierarchy Process (AHP), underscoring the inherent geographical predisposition of Ahoada East and West LGAs to inundation. Areas directly adjacent to river channels and those characterized by low-lying topography consistently exhibit the highest levels of physical exposure and, consequently, overall flood vulnerability. Secondly, the research highlights the significant role of socio-economic factors in amplifying flood vulnerability. Despite the dominance of physical indicators, the contribution of socio-economic sensitivity parameters, including high population density and the prevalence of informal or poorly constructed housing, was substantial. This indicates that even in areas with moderate physical exposure, a high concentration of vulnerable populations with limited resources and inadequate infrastructure can elevate the overall vulnerability to severe levels. This finding reinforces the notion that vulnerability is not solely a function of natural hazards but is deeply intertwined with socio-economic conditions and developmental disparities. Thirdly, the study implicitly reveals a generally low adaptive capacity across the study area. While adaptive capacity indicators were included in the MCDA, their relatively lower weights suggest that factors such as limited road network density, inadequate access to healthcare and education, and a lack of livelihood diversification contribute to a pervasive inability to cope with and recover from flood events. This pervasive low adaptive capacity means that once exposed and sensitive, communities in Ahoada East and West LGAs are highly susceptible to significant adverse impacts, perpetuating a cycle of disaster and recovery. Finally, the analysis underscores the critical interplay between environmental degradation and increased flood vulnerability. The existing literature, supported by the context of the study area, suggests that the degradation of natural protective ecosystems, such as mangrove forests, due to anthropogenic activities (e.g., oil spills, over-exploitation), exacerbates the region's susceptibility to flooding. This highlights the importance of integrating ecological health into flood risk management strategies, recognizing that a healthy ecosystem can provide vital natural defenses against flood hazards. In essence, the findings confirm that flood vulnerability in Ahoada East and West LGAs is a complex phenomenon resulting from the synergistic interaction of inherent geographical characteristics, socio-economic sensitivities, and limited adaptive capacities, further compounded by environmental degradation. The spatially explicit nature of these findings provides a robust foundation for developing targeted and integrated flood risk reduction strategies.

7. Contribution to Knowledge

This study makes several significant contributions to the existing body of knowledge on flood vulnerability assessment, particularly within the context of the Niger Delta region of Nigeria. While previous research has broadly addressed flood susceptibility and the application of GIS-based Multi-Criteria Decision Analysis (MCDA) in Nigeria, this study distinguishes itself through its localized, comprehensive, and integrated approach, thereby filling critical gaps in the literature.

Firstly, this research provides the first comprehensive and spatially explicit flood vulnerability map specifically for Ahoada East and Ahoada West Local Government Areas. Unlike broader regional assessments that often generalize vulnerabilities, this study offers a granular understanding of flood risk at a finer spatial resolution, identifying specific communities and areas within these LGAs that are most susceptible to flood impacts. This localized focus is crucial for effective disaster planning and resource allocation, as it moves beyond generic flood maps to provide actionable intelligence tailored to the unique socio-ecological context of the study area.

Secondly, the study contributes methodologically by demonstrating a robust application of the GIS-based MCDA framework, integrating a diverse set of physical, environmental, and socio-economic indicators. While GIS-MCDA has been used in other Nigerian contexts, this research meticulously details the selection, standardization, and weighting of indicators, particularly emphasizing the interplay between physical exposure and socio-economic sensitivity. The explicit consideration of factors such as housing quality, population density, and access to services within the MCDA framework provides a more holistic and realistic representation of vulnerability, moving beyond purely physical hazard assessments.

Thirdly, the findings offer empirical evidence that reinforces and refines existing theoretical frameworks of vulnerability, such as the IPCC framework (Exposure, Sensitivity, Adaptive Capacity) and the Pressure and Release (PAR) model. By demonstrating how inherent geographical characteristics, coupled with socio-economic disparities and environmental degradation, collectively amplify flood vulnerability in Ahoada East and West LGAs, the study provides a real-world case study that validates these theoretical constructs. It highlights how root causes and dynamic pressures manifest as unsafe conditions, leading to heightened vulnerability in specific spatial contexts. Furthermore, the study sheds light on the critical role of adaptive capacity in shaping overall vulnerability. While the analysis indicates a generally low adaptive capacity across the study area, its inclusion as a distinct component within the MCDA framework underscores its importance. This provides a baseline understanding for future interventions aimed at strengthening community resilience, emphasizing that effective flood risk reduction requires addressing not only the physical hazard but also the underlying socio-economic and institutional factors that limit a community's ability to cope and recover.

Finally, by identifying the specific contributions of various indicators to overall vulnerability, this research provides a scientific basis for targeted policy interventions. It suggests that efforts to mitigate flood risks in Ahoada East and West LGAs must be multi-faceted, encompassing not only infrastructural solutions but also socio-economic development programs, environmental conservation initiatives (e.g., mangrove restoration), and community empowerment strategies. This integrated perspective is a valuable contribution for policymakers, disaster management agencies, and non-governmental organizations working towards sustainable development and disaster risk reduction in the Niger Delta and other similar flood-prone regions globally.

8. Conclusion

This study embarked on a comprehensive geospatial analysis of flood vulnerability in Ahoada East and Ahoada West Local Government Areas of Rivers State, Nigeria, employing a GIS-based Multi-Criteria Decision Analysis (MCDA) approach. The overarching aim was to identify, map, and assess the spatial distribution of flood-prone areas and the varying degrees of vulnerability within these regions. The findings unequivocally demonstrate that flood vulnerability in the study area is a complex, multi-dimensional phenomenon, shaped by an intricate interplay of physical, environmental, and socio-economic factors. The generated flood vulnerability map serves as a critical visual tool, clearly delineating areas of varying risk levels across both LGAs. It highlights that regions in close proximity to major river systems and those characterized by low-lying topography are inherently more susceptible to inundation. This physical exposure, while a primary determinant, is significantly amplified by socio-economic sensitivities. High population densities, coupled with prevalent informal housing structures and limited access to essential services, transform areas of moderate physical risk into zones of high overall vulnerability. This underscores the critical role of human factors and developmental disparities in exacerbating the impacts of natural hazards. Furthermore, the study implicitly points to a pervasive low adaptive capacity within the communities, suggesting that despite recurring flood events, the ability of the population to effectively cope with and recover from these disasters remains constrained. This is a crucial insight, as it indicates that even with improved physical infrastructure, the underlying socio-economic fragilities will continue to render communities vulnerable. The degradation of natural ecosystems, such as mangrove habitats, further compounds this vulnerability by diminishing natural protective barriers, reinforcing the interconnectedness of social and ecological systems in determining resilience. In conclusion, the persistent and devastating impact of floods in Ahoada East and Ahoada West LGAs is a direct consequence of the synergistic interaction between inherent geographical predispositions, acute socio-economic sensitivities, and limited adaptive capacities. The spatially explicit insights provided by this research offer a robust foundation for evidence-based decision-making. It is clear that effective flood risk management in these areas requires a holistic and integrated approach that transcends traditional hazard-centric views, addressing both the physical drivers of flooding and the underlying human vulnerabilities that amplify its destructive consequences.

9. Recommendations

Based on the comprehensive geospatial analysis of flood vulnerability in Ahoada East and Ahoada West Local Government Areas, the following recommendations are put forth to guide policymakers, disaster management agencies, local communities, and other stakeholders in developing and implementing effective flood risk reduction and resilience-building strategies: (1) Implement Targeted Flood Risk Management Plans: The generated flood vulnerability map should be utilized as a primary tool for identifying and prioritizing high-risk zones within Ahoada East and Ahoada West LGAs. Resources for flood mitigation, preparedness, and response should be strategically allocated to these areas. This includes developing localized early warning systems, establishing safe evacuation routes, and identifying temporary shelters in less vulnerable locations. (2) Promote Flood-Resilient Infrastructure and Housing: Encourage and enforce building codes that promote flood-resilient construction practices, particularly in identified high-vulnerability zones. This could involve elevating structures, using water-resistant materials, and designing improved drainage systems at the community level. Government and non-governmental organizations should provide support and incentives for vulnerable households to adopt these practices. (3) Strengthen Socio-Economic Resilience: Address the underlying socio-economic vulnerabilities that amplify flood impacts. This includes implementing poverty alleviation programs, promoting livelihood diversification (e.g., away from solely flood-dependent agriculture), and improving access to basic services such as healthcare, education, and clean water. Enhanced social protection mechanisms should be put in place to support affected populations during and after flood events. (4) Invest in Environmental Restoration and Conservation: Prioritize the restoration and conservation of natural flood defense mechanisms, particularly mangrove ecosystems along the riverine areas. Reforestation efforts, coupled with strict enforcement against illegal logging and pollution (especially from oil exploration activities), can significantly enhance the natural capacity of the landscape to absorb floodwaters and reduce their destructive force. This aligns with the principles of ecosystem-based disaster risk reduction. (5) Enhance Community Engagement and Capacity Building: Foster active participation of local communities in flood risk assessment and management. This involves integrating traditional knowledge with scientific data, conducting regular awareness campaigns on flood preparedness, and training community members in first aid, search and rescue, and early warning dissemination. Empowering communities to take ownership of their flood resilience efforts is crucial for sustainable outcomes. (6) Improve Data Collection and Monitoring: Establish a robust system for continuous data collection on rainfall patterns, river levels, land-use changes, and socio-economic indicators. Regular updates to the flood vulnerability map using the latest geospatial data and techniques will ensure that risk assessments remain relevant and accurate. Collaboration between government agencies, research institutions, and local communities in data sharing and monitoring is essential. (7) Integrate Flood Risk into Land-Use Planning: Incorporate flood vulnerability assessments into regional and local land-use planning and zoning regulations. This will guide future development away from high-risk areas, prevent encroachment on floodplains, and ensure that new settlements are developed in a manner that minimizes exposure and enhances resilience. Strategic planning for urban and rural development should consider long-term climate change projections. (8) Foster Inter-Agency Collaboration: Promote seamless coordination and collaboration among various government agencies (e.g., disaster management, environmental protection, urban planning, agriculture, health), non-governmental organizations, and international partners. A multi-sectoral approach is vital for addressing the complex and interconnected challenges of flood vulnerability in a holistic and effective manner. By implementing these recommendations, Ahoada East and Ahoada West LGAs can move towards a more proactive and sustainable approach to flood risk management, ultimately building more resilient communities capable of adapting to the increasing challenges posed by climate change and environmental hazards.

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