APPLICATION OF REMOTE SENSING AND GIS IN FLOOD RISK ASSESSMENT: A CASE STUDY OF EKET LGA, AKWA IBOM STATE

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***Abstract*— The comprehension of Earth has a significant impact on how humans will live in the future. One of the environmental issues that affects not only Eket L. G. A. but the entire state of Akwa Ibom is flooding. Floods have become much more frequent worldwide in recent years due to a variety of factors, including climate change, the loss of soil and vegetation that absorb water, urbanization, population growth, and runoff obstruction. Food security has been jeopardized, and lives and property have been lost as a result. In order to lessen the incalculable and disastrous effects of flooding, new tools and capabilities have been made available by the development and integration of spatial technologies like remote sensing (RS), geographic information systems (GIS), and global positioning systems (GPS). In order to map out the risk areas within the Eket local government, the study used space-based technologies. ArcGIS 10.5 and ERDAS IMAGING 9.2 were used to process the LandSat-8 ETM+, SRTM, and ASTER DEM imagery in order to create the slope, elevation, contour, Flow Accumulation, and Stream Order Network. Additionally, supervised image classification was carried out in order to obtain the Land Use Land Cover map of the study area. Flood risk maps in three zones, high, medium, and low risk were created by combining the results. GIS has proven to be a useful tool for mapping flood risk assessment. This will help decision-makers and planners with flood management and implementation.**

Keywords*— *Flooding, Space Technology, Flood Risk Zone, Climate Change, Remote Sensing

1. INTRODUCTION

The sustainability of human existence is closely tied to our understanding and management of the Earth's systems. Ozone layer depletion, biodiversity loss, desertification, flooding, erosion, watershed degradation, deforestation, and wildfires are just a few of the growing environmental issues that have drawn attention from all over the world. Destructive processes are becoming more frequent and larger in scope, endangering the planet's physical, chemical, and biological integrity every day. Even though some effects take time to manifest, flooding, coastal erosion, and gully erosion are already having a devastating effect on many communities worldwide, resulting in a considerable loss of life and property. Extreme hydro meteorological events are largely caused by climate change, especially global warming.

Increased moisture concentration from warmer air increases the frequency and intensity of rainfall, increasing the risk of flooding (Chukwuma et al., 2021). These intense precipitation events frequently lead to dangerous situations like landslides and floods. According to projections, many urban areas will become more susceptible to extreme flooding events as a result of the combined effects of land-use change and climate variability (Chukwuma et al., 2021). By substituting impervious surfaces for natural vegetation and soil cover, urbanization increases surface runoff and makes areas more vulnerable to flooding (Kaspersen et al., 2015; Pradhan-Salike & Pokharel, 2017).

Flooding is acknowledged as one of the most destructive and pervasive natural hazards in the world because of its high frequency and catastrophic socioeconomic effects, (Anukwe et al., 2020). Floods in Nigeria are a serious threat to infrastructure, livelihoods, and human lives; they frequently cause victims to be displaced, suffer financial losses, and become impoverished (Okafor, 2020). Extreme rainfall and flooding events have increased significantly in recent decades, with worsening economic and human consequences. Flood hazards can take many different forms, such as soil erosion, structural damage, contaminated food and water supplies, disruption of communication and transportation networks, and mass displacement (Hewitt, 1971).

Strong rainfall, climate change, poor drainage systems, trash-clogged streams, building on floodplains, and fast urban population growth are the main causes of flood disasters in Nigeria (Adeoye, 2009). The magnitude and intensity of flood disasters are increased by the frequent interaction of these factors. The conversion of natural landscapes, like farmlands and wetlands, into built-up environments is accelerated by urban expansion in particular, increasing exposure in flood-prone areas.

Accurate geographic data on hazards and vulnerable areas is necessary for effective flood disaster risk reduction. Thus, mapping hazards and vulnerabilities is essential to disaster management and preparedness.

Although levees and dams are examples of structural flood control measures that can lower risk, their economic, social, and environmental costs are frequently prohibitive. As a result, integrated strategies like early warning systems, flood forecasting, and spatial risk mapping are becoming more and more acknowledged as affordable substitutes. Geographic Information Systems (GIS) and remote sensing are useful tools for managing and accessing flood hazards. By providing synoptic and temporal views of hydrological processes, these technologies make it possible to estimate the areas that have been inundated, identify vulnerable populations and infrastructure, and monitor flood dynamics (Izinyon, 2011). But when it comes to disaster management, Nigeria has been sluggish to embrace geospatial technologies.

This is demonstrated by the poor response to the recent flood disasters that impacted over 23 states, killed many people, destroyed property, and endangered biodiversity. Effective flood risk reduction depends on having precise information about the frequency, size, and geographic distribution of dangerous occurrences as well as the vulnerabilities of impacted communities and property. Effective flood disaster management is made more difficult by the fact that such data is still scarce in many Nigerian cities.

2.0 OVERVIEW OF THE RESEARCH PROBLEM AND JUSTIFICATION FOR THE STUDY

2.1 THE RESEARCH PROBLEM AND THE AIM OF THE STUDY

One of the most destructive natural disasters in the world, floods cause a great deal of property damage and a considerable number of fatalities. More people are displaced by flooding in Nigeria than by any other hazard, and it continues to pose a serious threat to infrastructure and communities. According to estimates, at least 20% of Nigerians are at risk of flooding in one way or another. The scale of the issue is demonstrated by the flood disaster of 2012, when the National Emergency Management Agency (NEMA) reported that rivers overflowed due to excessive rainfall between July and October, submerging large farmlands, displacing 1.3 million people, and killing 431 people. In total, 23 states were impacted, with both developed and undeveloped regions suffering significant consequences.

A paradigm shift in disaster management from post-disaster relief efforts to proactive disaster preparedness and mitigation has been brought about by the increasing frequency and severity of flooding. Governments and institutions are placing more emphasis on preventive measures to lessen vulnerability and increase resilience than just distributing aid after disasters happen.

Flooding has an indiscriminate effect on everyone who is unprepared. However, precise spatial data to aid in planning and decision-making is necessary for efficient flood risk management. Mapping vulnerable areas, determining flood risk, and directing sustainable flood disaster management are all made possible by geoinformation technologies like Geographic Information Systems (GIS) and Remote Sensing (RS). However, in Nigeria, these technologies are still underutilized, exposing numerous communities to the risk of flooding.

In view of the identified research problems, the aim of this study is to map flood-vulnerable areas in Eket Local Government Area, Akwa Ibom State, using space-based geospatial technologies. The specific objectives are to:

i. Generate, classify, and assess the terrain categories that are susceptible to flood disasters in Eket.
ii. Develop a database on flood vulnerability for selected communities and demonstrate spatial analysis of their susceptibility to flooding.

2.2 JUSTIFICATION FOR THE STUDY

Effective flood disaster mitigation requires a thorough understanding of the frequency, severity, and features of dangerous events as well as the vulnerabilities of people, infrastructure, and economic activity in areas that may be impacted. Unfortunately, most developing-world cities, especially those in Nigeria, frequently lack this kind of in-depth knowledge. Early detection of areas at risk and the application of preventative measures that encourage readiness, efficient response, quick recovery, and long-term prevention are two of the best ways to lessen the effects of flooding. Reliable data on important flood risk indicators, including elevation, slope orientation, settlement proximity to drainage channels, drainage network efficiency, availability of natural buffers, extent of inundation, and sociocultural practices that affect vulnerability, are necessary to accomplish this. Analyzing large-scale weather data and time series, as in (Oloyede *et al.,* 2022) provides a robust method for understanding temperature distribution and other climatic factors that influence flood occurrences.

Strong data collection and analysis techniques are necessary to produce this information. One of the best methods for assessing flood risk and preparing for disasters is the combination of Remote Sensing (RS) and Geographic Information Systems (GIS). Flood hazard maps produced by these geospatial technologies are precise and simple to understand, making them essential resources for planners and decision-makers. These maps help prioritize mitigation and response efforts, which lowers the risks and impacts of flooding on communities, in addition to supporting appropriate land-use planning in flood-prone areas. Figure 1 depicts a series of photographs that illustrate the devastating consequences of recurrent flooding within the study area, highlighting its widespread impacts on the environment, infrastructure, and local communities

Figure 1: Sample incident of flood disaster across different part of Nigeria.

3 METHODOLOGY

3.1 THE STUDY AREA

Eket is one of the Thirty-one Local Government areas of Akwa Ibom state with a land mass of 176,000 square km and population of 172, 557 (NPC, 2006). It occupies the south central portion of the state located between Latitude 4 33" and 4 45" Eastern wards, Longitude 7 52", 5 02". Eket is bounded on the North by Nsit Ubium local government on the East by Esit Eket, on the west by Onna and the South by Ibeno local government/ Bight of Bonny. The physical relief of Eket is basically flat, though with some marshy river- washed soils around the banks of Qua-Iboe River. It falls within the tropical zone wherein its dominant vegetation is the green foliage of trees/shrubs and the oil palm tree belt. The local government has two seasons: the wet and dry season. Figure 2 presents the study area map, illustrating the geographic location of Eket Local Government Area within Akwa Ibom State, Nigeria. The map delineates its administrative boundaries, showing its spatial extent in relation to neighboring Local Government Areas and its position within the southeastern part of the state. This provides a spatial context for understanding the area's environmental and socio-economic characteristics relevant to the study.

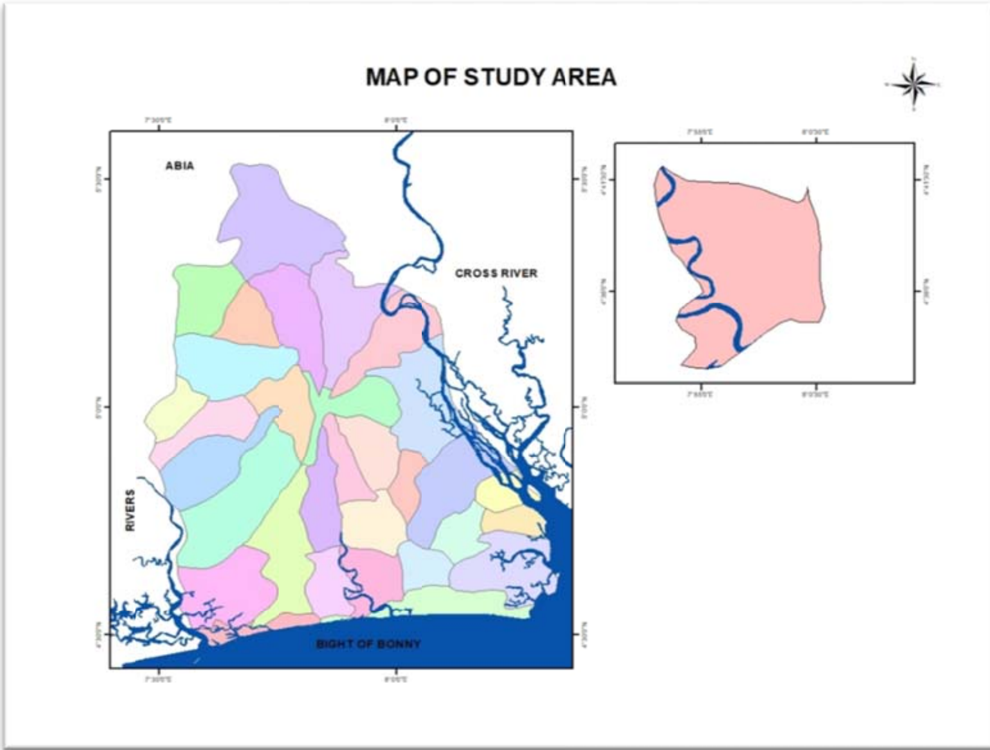

Figure 2: Map showing the study area

3.2 DATA ACQUISITION AND PROCESSING

The European Space Agency (ESA) archives provided the Shuttle Radar Topography Mission (SRTM), Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) DEM, and Landsat-8 OLI/TIRS satellite imagery used in this study. ArcGIS 10.5 and ERDAS IMAGINE 9.2 were used to process the datasets. Elevation, slope, flow direction, accumulation, and stream network layers were all derived using SRTM and ASTER DEMs, and the study area's Land Use/Land Cover (LULC) map was created using Landsat-8 imagery.

For spatial consistency, all datasets were re-projected to UTM Zone 32N (WGS84 datum). Before being integrated for flood risk analysis, vector datasets were rasterized and raster layers were reclassified using ArcGIS's Spatial Analyst extension.

3.2.1 FLOOD VULNERABILITY MODELING

First, a fill operation was applied to the Digital Elevation Model (DEM) in order to eliminate sinks and guarantee precise surface hydrology. Flow Accumulation found cells where water converges, suggesting possible flood-prone areas, while Flow Direction was developed to mimic the downslope movement of water. The Hydrology toolset was used to extract and analyze stream networks.

3.2.2 IMAGE CLASSIFICATION

Landsat-8 imagery (acquired in July 2020, UTM Zone 32N, WGS84) was subset to the Eket LGA boundary and subjected to digital image processing. The workflow included:

i. Pre-processing: Radiometric corrections were applied to minimize the effects of sensor noise, atmospheric conditions, and illumination differences.

ii. Image Enhancement: Contrast stretching was used to improve visual interpretation by adjusting pixel brightness values.

iii. Supervised Classification: Based on prior knowledge of the study area, the Maximum Likelihood algorithm was applied using bands 4, 3, and 2 (visible and near-infrared).

Six LULC classes were identified and they are:

a) Water bodies (rivers, streams, wetlands, lakes)
b) Built-up areas (residential, commercial, roads, pavements)
c) Cultivation (farmlands and croplands)
d) Vegetation (grasses, open fields, shrubs)
e) Forest (natural forest, palm/rubber plantations)
f) Bare land (exposed soil and non-vegetated surfaces)

3.2.3 Basin and Drainage Analysis

Drainage basins were defined using ArcGIS's Basin tool and the ASTER DEM. Water pathways and possible inundation zones were modeled using the Flow Direction and Flow Accumulation outputs. While Flow Accumulation pinpointed areas of water convergence and highlighted communities most vulnerable to flooding during periods of heavy rainfall, Flow Direction maps offered insights into runoff pathways.

4 RESULTS AND DISCUSSION

The spatial analysis of flood risk in Eket and environs reveals distinct patterns of vulnerability shaped by topography, settlement distribution, and land use/land cover characteristics.

4.1 FLOOD RISK DISTRIBUTION

The flood risk map delineates four risk zones, high, medium, low, and minimal risk—across the study area. High flood risk zones, concentrated in the southern and southwestern portions, correspond to low-lying terrain with gentle slopes and poorly drained soils. These locations are prone to seasonal inundation, posing serious threats to settlements and agricultural activities. Medium-risk zones extend across the central belt, acting as transitional areas where flooding occurs episodically, particularly during peak rainfall. Low-risk zones dominate the northern and northeastern regions, where elevated terrain and better drainage provide relative protection against flooding. This gradient highlights the geomorphological control on flood dynamics in the area.

4.2 EXPOSURE OF BUILDINGS TO FLOOD HAZARDS

The building-at-risk map overlays settlement distribution on the flood risk zones, providing insights into human vulnerability. A significant proportion of buildings are situated in medium-risk zones, exposing a large share of the population to moderate flood hazards. More critically, clusters of buildings are also located within high-risk floodplains, particularly in the southern and central sectors. These structures are highly vulnerable to recurrent flooding, with implications for property damage, livelihood disruption, and displacement. In contrast, fewer buildings occur in low-risk areas, suggesting that safer elevated terrain remains underutilized, possibly due to accessibility or socio-economic constraints. This misalignment between settlement patterns and environmental suitability underscores the need for risk-informed land use planning.

The map in Figure 12 reveals the spatial distribution of settlements across the flood risk zones. Larger settlements are predominantly situated in low-risk areas, while smaller clusters, particularly those highlighted in circles, are located within zones prone to flooding. Based on spatial analysis, the total land area of Eket LGA is approximately 30,476 km^2. Of this, 12,794.63 km^2 (high risk), 8,081.78 km^2 (medium risk), 7,618.95 km^2 (low risk), and 1,980.68 km^2 (not at risk) were delineated. This pattern demonstrates that about 75% of settlements are concentrated in relatively safe zones, reflecting a preference for less vulnerable terrain, though encroachment into high-risk floodplains remains evident. Similar settlement dynamics in relation to flood risk have been reported in other parts of the Niger Delta, where population pressure and land scarcity drive habitation into environmentally fragile areas despite the associated hazards (Aderoju et al., 2020; Akukwe & Ogbodo, 2015; Eze & Efiong, 2010).

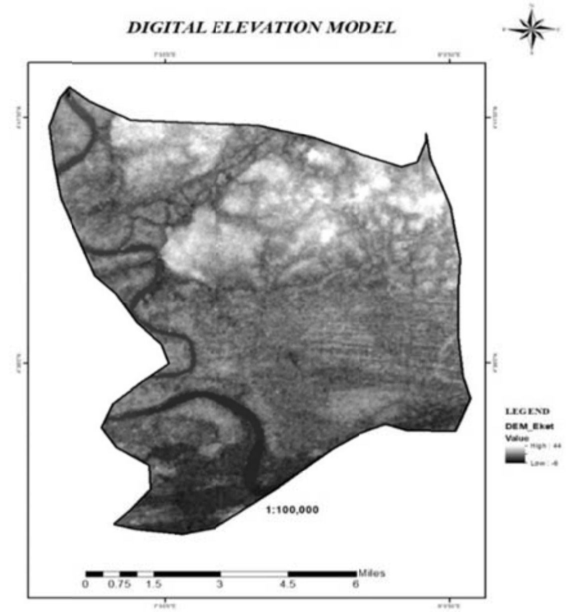

Figure 3: The DEM of the study area

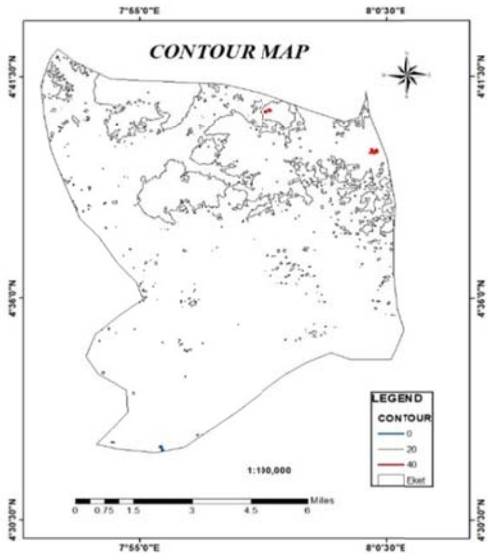

Figure 4: The Contour Map of the study area

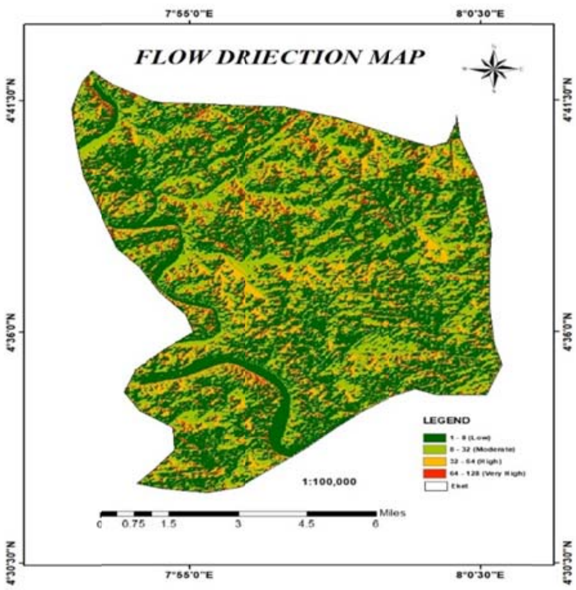

Figure 5: Map showing flow direction

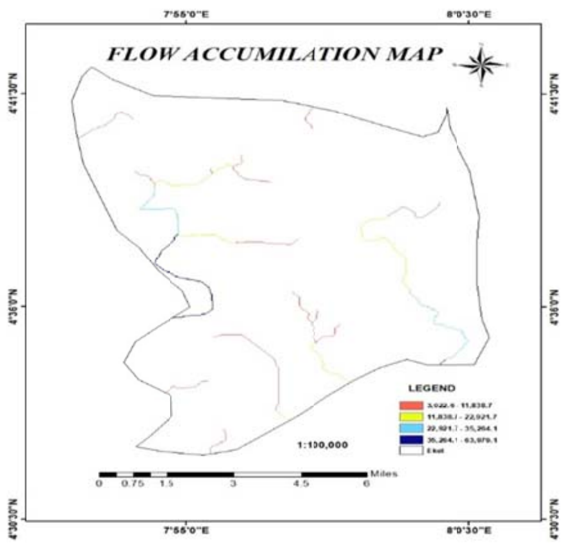

Figure 6: Map showing flow accumulation of the study

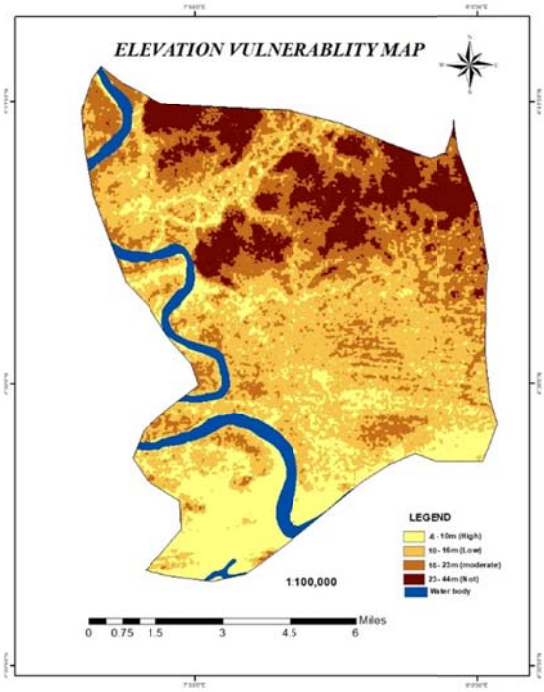

Figure 7: Elevation Vulnerability map

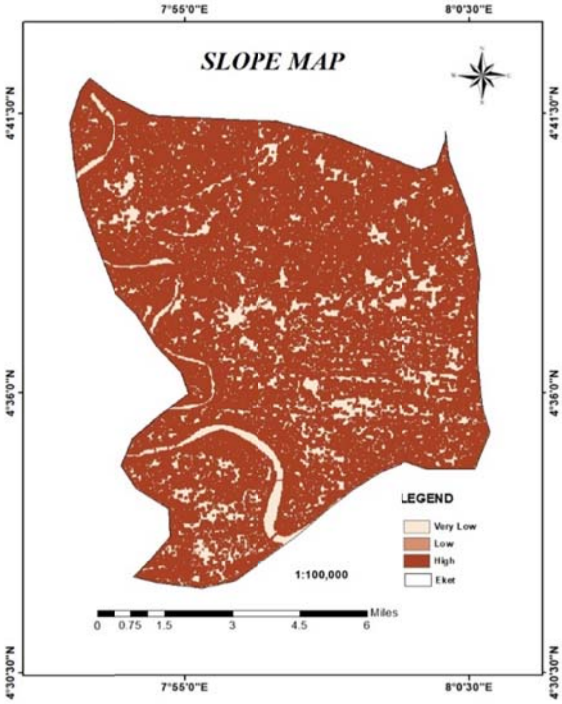

Figure 8: The slope map of the study area

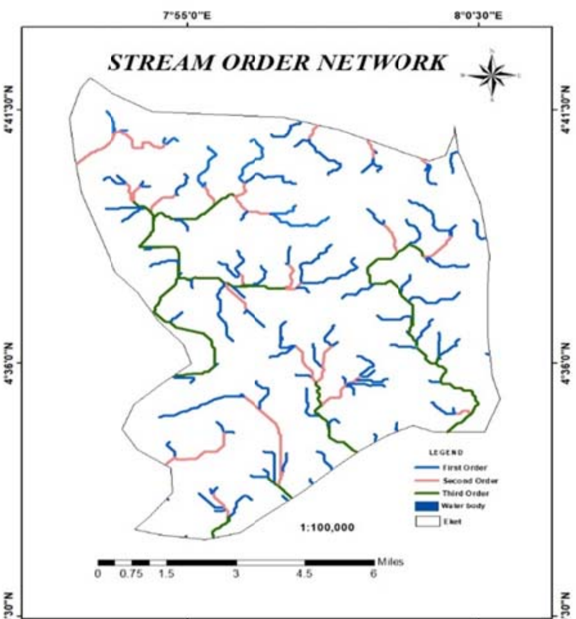

Figure 9: Steam network of Eket

LAND USE LAND COVER OF EKET

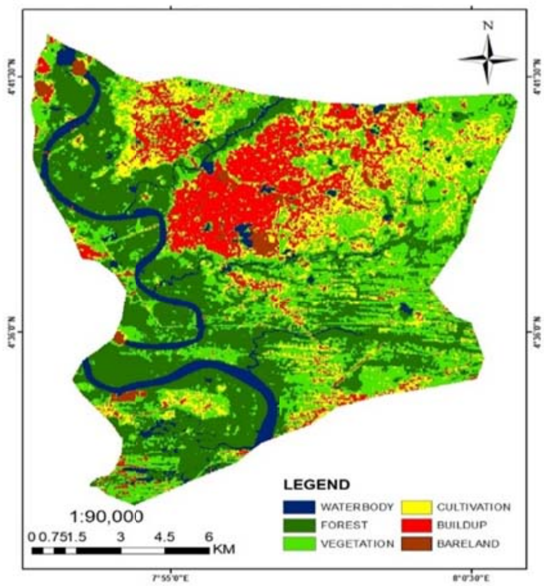

Figure 10: Land use Land cover of the study

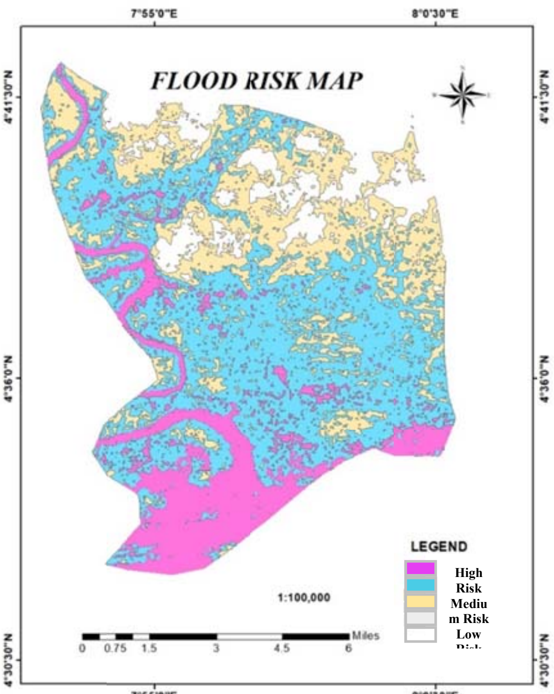

Figure 11: The Flood Risk Map

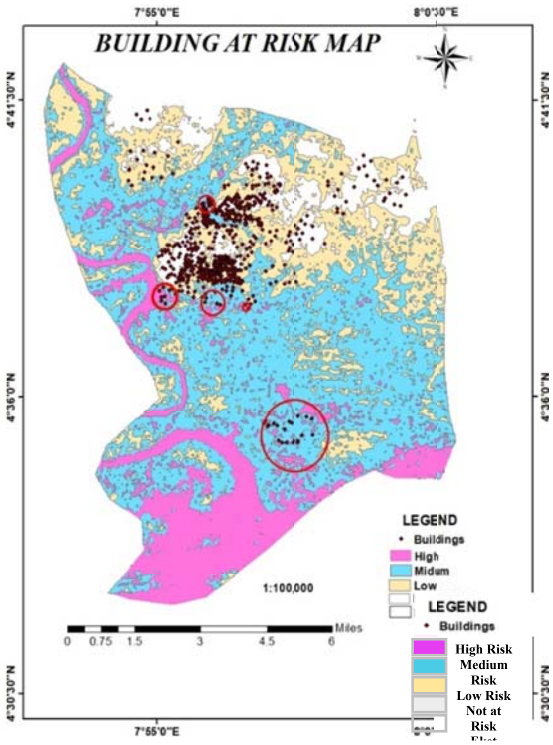

Figure 12: Map showing the Buildings that are at Risk

Table 1: The Area at Risk

CATEGORY	COUNTS (M)	TOTAL ESTIMATED AREA (KM)
HIGH RISK	56,865	12,794.625
MEDIUM RISK	35, 919	8,081.775
LOW RISK	33, 862	7, 618.95
NOT AT RISK	1,080. 675	1,980.675

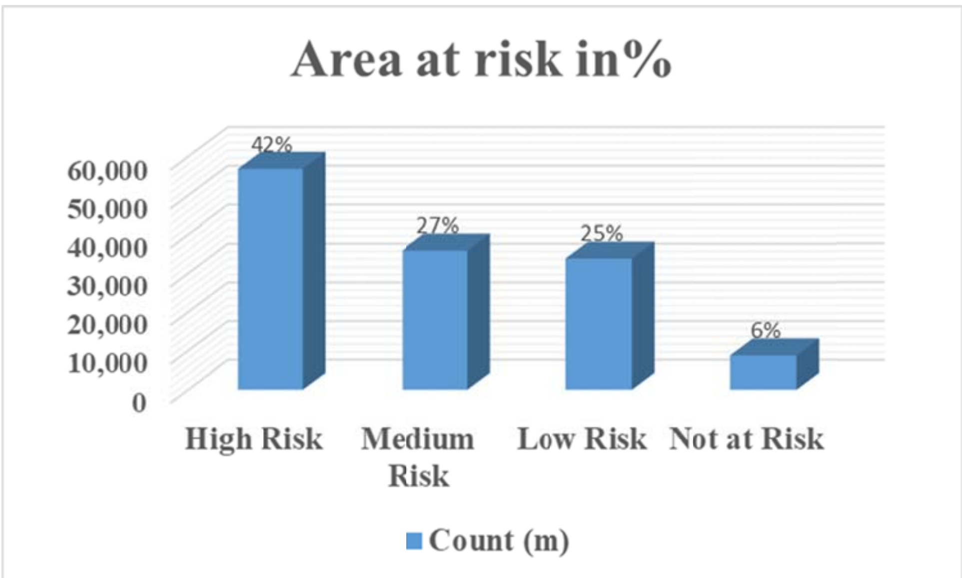

Figure 13: The bar chart for the Area at Risk

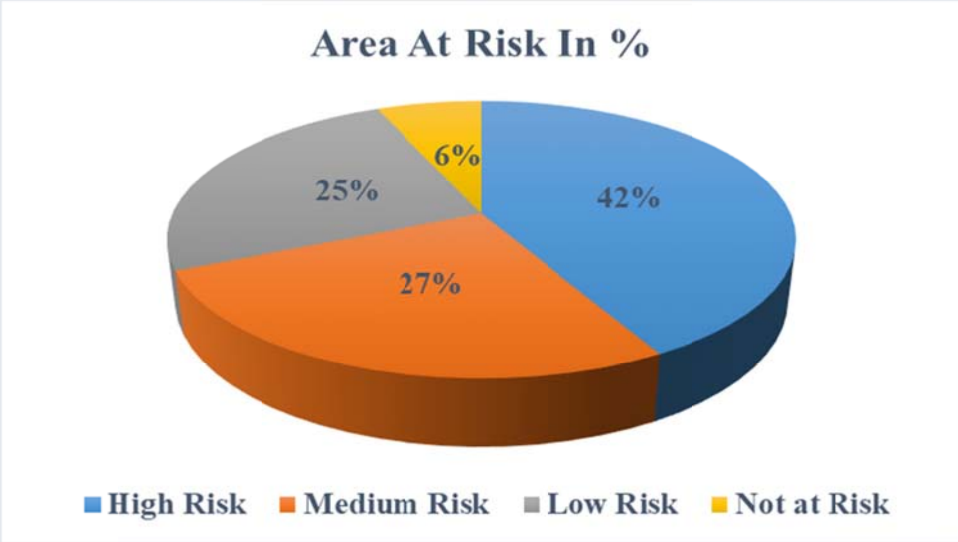

Figure 14: The pie chart for the Area at Risk

4.3 DISCUSSION

Different patterns of vulnerability influenced by topography, settlement distribution, and land use/land cover characteristics are revealed by the spatial analysis of flood risk in Eket and the surrounding area.

Model of Digital Elevation: A digital representation of the topography of the Earth's surface represented as a continuous grid of elevation values is called a digital elevation model, or DEM. The DEM was used in the flood risk assessment of Eket to examine the terrain's features, including elevation, slope, and drainage patterns. These elements are essential because: Potential flood-prone zones are indicated by low-lying areas in the DEM. Faster runoff from steeper slopes reduces water accumulation but increases the risk of erosion. Flood retention or pooling areas are frequently represented by surface depressions obtained from DEM data.

Flood retention or pooling areas are frequently represented by surface depressions obtained from DEM data. Figure 3 illustrates how hydrological modeling and flow direction/accumulation analyses were performed by integrating DEM into GIS to identify areas that could be inundated.

4.3.1 Contour map:

The contour map produced from the DEM is shown in Figure 4, which shows lines of uniform elevation throughout the terrain. The contour map had several uses in the flood risk assessment of Eket. It helped identify watersheds and drainage divides that affect surface water flow, showed valleys, ridges, and low-lying plains where infrastructure and habitations may be at risk of flooding, and clearly visualized topographic variation within the study area. Additionally, the contour map improved knowledge of how elevation gradients regulate surface runoff pathways during periods of intense rainfall and validated the flood risk zones derived from the DEM.

4.3.2 Flow Direction

The path surface water takes as it travels across the terrain downslope is referred to as the flow direction. It is obtained from the DEM by using the D8 algorithm to assign a direction to each grid cell that corresponds to the steepest descent toward one of its eight neighboring cells, as shown in Figure 5. The flow direction model played a crucial role in mapping the patterns of water movement throughout the landscape as part of the Eket flood risk assessment. It helped define drainage networks and catchment boundaries by shedding light on how rainfall runoff moves through slopes, valleys, and depressions. As a result, it became easier to identify areas with naturally concentrated surface water, which frequently coincide with stream channels and low-lying flood-prone areas.

4.3.3 Flow Accumulation

Figure 6 shows the flow accumulation map, which highlights areas of water convergence by counting the number of upstream cells supplying runoff to a specific location on the landscape. High flow accumulation values in the Eket flood risk assessment correlated with possible flood pathways and stream channels, whereas low values were linked to elevated terrain and ridges. Finding the areas where runoff tends to concentrate and are most vulnerable to flooding during periods of heavy rainfall was made easier with the help of this analysis. The delineation of drainage basins, flood-prone zones, and areas needing both structural and non-structural flood control interventions was made possible by the more realistic simulation of runoff dynamics that flow accumulation offered when combined with the flow direction model.

4.3.4 Elevation Vulnerability Map

A thematic layer derived from the DEM, the elevation vulnerability map (shown in Figure 7) categorizes the study area based on relative heights above sea level. Elevation is a crucial factor in determining flood risk because coastal lowlands make up the majority of Eket. Moderately elevated zones (10–30 m) pose a moderate risk because they may serve as runoff collection points depending on slope and drainage conditions; high elevation zones (> 30 m) are relatively less exposed to direct flooding but contribute runoff to lower-lying plains; and low-lying areas (< 10 m) are highly vulnerable to tidal influence, storm surges, and pluvial flooding. By demonstrating the relationship between terrain elevation and flood susceptibility, the elevation vulnerability map provided valuable insights into the spatial distribution of flood hotspots across Eket's urban and peri-urban landscapes

4.3.5 Slope Map:

Slope Map: Derived from DEM analysis, the slope map in Figure 8 illustrates the rate of elevation change throughout the terrain. Areas with mild slopes (0–5%) were identified as extremely vulnerable in the flood risk assessment of Eket because they promote water stagnation and protracted flooding.

Although they made drainage easier, moderate slopes (5–15%) could still cause water to pool in depressions. Although steep slopes (> 15%) were more likely to experience erosion and rapid runoff, they were less likely to experience flooding. Therefore, the slope map was crucial for assessing flood persistence, infiltration potential, and runoff velocity.

4.3.6 Stream Order

The hierarchical arrangement of streams and rivers in a drainage network according to their relative locations and levels of connectivity is known as stream order. As shown in Figure 9, stream order was determined in the Eket flood risk assessment by applying the Strahler method to the flow direction and flow accumulation outputs of the DEM. Throughout Eket's uplands, first-order streams—the tiniest channels usually found in headwater areas—were discovered to serve as the first collectors of runoff. While higher-order streams (fourth order and above) represent major drainage pathways that convey significant water volumes downstream, second- and third-order channels, which function as intermediate drainage lines, were formed when two or more first-order streams converged.

In order to assess drainage density and hydrological connectivity and to identify flood-prone channels where higher-order streams concentrate runoff from upstream areas, stream order mapping was essential. In addition, it provided an assessment of the carrying capacity of natural drainage systems relative to urban growth and rainfall intensity. All things considered, the stream order map helped identify critical flood risk zones by providing important information about the movement of water from upland catchments to lowland floodplains.

4.3.7 Flood Risk Distribution

Four risk zones, high, medium, low, and minimal risk—are identified throughout the study area by the flood risk map. as illustrated in figure 11. Low-lying areas with mild slopes and poorly drained soils are associated with high flood risk zones, which are primarily found in the southern and southwestern regions. Settlements and agricultural operations are seriously threatened by these areas' propensity for seasonal flooding. The central belt is divided into medium-risk zones, which serve as transitional regions where flooding happens sporadically, especially during periods of high precipitation. The northern and northeastern areas are dominated by low-risk zones, where improved drainage and higher elevation offer some degree of protection from flooding. This gradient draws attention to the area's geomorphological control over flood dynamics.

4.3.8 Exposure of Buildings to Flood Hazards

Human vulnerability is revealed by the building-at-risk map in Figure 12, which superimposes the distribution of settlements on the flood risk zones. Many buildings are located in medium-risk areas, putting a sizable portion of the populace at moderate risk of flooding. More importantly, building clusters, especially in the central and southern sectors, are situated within high-risk floodplains. These buildings are extremely susceptible to frequent flooding, which could result in displacement, disruption of livelihoods, and property damage. Conversely, there are fewer structures in low-risk locations, indicating that safer elevated terrain is still underutilized, perhaps as a result of socioeconomic or accessibility issues. This discrepancy between environmental suitability and settlement patterns emphasizes the necessity of risk-informed land use planning.

The spatial distribution of settlements throughout the flood risk zones is shown on the map in Figure 12. While smaller groups, especially those indicated by circles, are found in flood-prone areas, larger settlements are primarily found in low-risk areas. Eket LGA's total land area, according to spatial analysis, is roughly 30,476 km². The following were identified and shown in Table 1, Charts 1 and 2: 12,794.63 km² (high risk), 8,081.78 km² (medium risk), 7,618.95 km² (low risk), and 1,980.68 km² (not at risk). Despite the continued encroachment into high-risk floodplains, this pattern shows that approximately 75% of settlements are concentrated in relatively safe zones, indicating a preference for less vulnerable terrain.

Similar settlement dynamics in relation to flood risk have been reported in other parts of the Niger Delta, where population pressure and land scarcity drive habitation into environmentally fragile areas despite the associated hazards

(Aderoju et al., 2020; Akukwe & Ogbodo, 2015; Eze & Efiong, 2010).

4.3.9 Influence of Land Use And Land Cover

The land use/land cover (LULC) map provides further context to flood vulnerability. Built-up areas, concentrated in the central and northeastern parts of Eket, are highly exposed due to impervious surfaces that increase runoff. Cultivation areas, scattered across the central and southern regions, also contribute to moderate flood risk, particularly where farmland encroaches upon riverbanks and floodplains. In contrast, forested and vegetated zones, which dominate the east and west, play a protective role by enhancing infiltration, reducing runoff, and stabilizing soils. Bare land areas, though limited, exacerbate flooding and erosion where present, while waterbodies represent the natural drainage system that dictates flood pathways. The spatial overlap between high-risk flood zones, dense settlements, and built-up/cultivated areas suggests that land cover change driven by human activity has intensified vulnerability.

4.4 IMPLICATIONS FOR FLOOD MANAGEMENT

Collectively, the three maps demonstrate that flood risk in Eket is not merely a function of physical geography but is compounded by settlement patterns and land use practices. The concentration of buildings in flood-prone areas, combined with the expansion of impervious surfaces and encroachment on natural floodplains, heightens exposure. Conversely, areas with dense vegetation and forest cover offer natural buffers against flooding but are under increasing threat from land conversion. These findings highlight the need for integrated flood management strategies, including enforcement of zoning regulations, promotion of settlement in low-risk zones, preservation of forest and vegetated areas, and investment in flood mitigation infrastructure. Incorporating such measures into urban planning and disaster risk reduction frameworks will help safeguard lives, property, and livelihoods in Eket and its environs.

5. CONCLUSION

The ASTER DEM and the Basin tool in ArcGIS were used to define drainage basins. The Flow Direction and Flow Accumulation outputs were used to model water pathways and potential inundation zones. Flow Direction maps provided information on runoff pathways, while Flow Accumulation identified locations of water convergence and indicated communities most at risk of flooding during times of intense precipitation.

Proactive flood management techniques are desperately needed in Nigeria due to the rising frequency and severity of flooding events. This study's use of space-based technologies provides a dependable and affordable method of assessing flood risk, especially in developing nations where ground-based data is frequently scarce. To provide a more thorough understanding of flood risks and to support adaptive planning at local and regional scales, future research should include community-based risk assessments, socioeconomic vulnerability indices, and climate projections.

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