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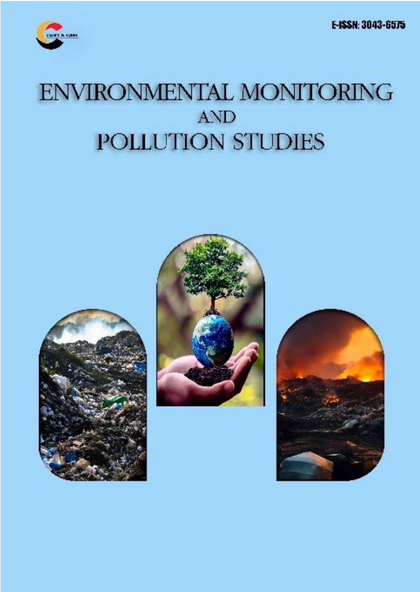

Exploring Climate Change Impacts on Disaster Risk Management: Environmental Risk Assessment in Abia State, Nigeria

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Abstract

Climate change has significantly impacted disaster risk management, particularly in regions prone to environmental hazards. In Abia State, Nigeria, flooding has emerged as a predominant environmental risk, exacerbated by increasing rainfall intensity and urbanization. This study aimed to assess the environmental vulnerability of Abia State to flooding using Geographic Information System (GIS) and Remote Sensing (RS) techniques. Key variables such as land use, elevation, proximity to drainage networks, and soil texture were analysed to develop a comprehensive flood vulnerability map. The results indicate that 33.21% of the study area is highly vulnerable to flooding, 43.26% is moderately vulnerable, and 23.53% is lowly vulnerable. The most affected areas include Ukwa West, Ukwa East, Aba South, and Ugwunagbo Local Government Areas. The study underscores the need for proactive disaster risk management strategies, integrating urban planning and sustainable environmental management to mitigate flood risks effectively.

Keywords: Climate Change, Geographic Information System (GIS), Environmental Risk, Flood Disaster, Disaster Risk Management

Introduction

Environmental risk simply refers to the disaster which affects lives and properties within environment as a result of the actions of man and other natural phenomenon (Oviosu & Enakireru, 2022). Environmental risks in Nigeria are of different types ranging from pollution, Ozone layer depletion, land degradation, flooding, global warming, deforestation, soil erosion and atmospheric contamination. Many of the environmental risk have increased over the years as a result of climate change impact. Associated with climate change, heavy rainfall is one of the main natural causes of flooding. Asare-Kyei et al. (2015) and Li et al. (2022) argued that as a result of growing populations, socioeconomic changes, and agricultural expansion, in recent years, flooding has been frequently reported in Nigeria and Abia state inclusive.

In 2001 collectively 500 people died as a result of flood in Abia, Adamawa and Akwa Ibom states respectively (Bashir et al., 2012; Danhassan et al., 2023). Historically, West Africa (including Nigeria) has been subject to extreme climate variability and severe weather events, such as floods, that can be attributed to climate change (Tabari, 2020). Climate change is believed to exacerbate floods across Nigeria by increasing rainfall intensity and duration (Ekwueme & Agunwamba, 2020). Due to global warming, extreme precipitation events and flooding risks, especially along riverbanks, will intensify, increasing the intensity of the hydrological cycle (Komolafe et al., 2021; Danhassan et al., 2023). Tabari Tabari (2020) observed that several areas of the globe, including Nigeria, are projected to experience increased flood intensity in upcoming years.

In Nigeria, urban floods are characteristic of cities such as Aba, resulting mainly from poor planning and land use, poor drainage network and indiscriminate dumping of refuse into drains and streams among others (Ogbonna et al., 2015). Flooding has been a major and recurrent environmental problem in Aba. It has wide ranging environmental and socio-economic effects, and also endangers human live. Some of these effects include, damage to transport infrastructure which can disrupt transport, communication and other economic activities, damage to property and surface water pollution. Flooding is the most common natural hazard affecting Abia state at present. In the study area, the problem of flooding has so far been difficult to mitigate (Ogbonna et al., 2015).

From a climate change standpoint, identifying vulnerability is important for the development of mitigation strategies and adaptation policies necessary for sustainable development (Komolafe et al., 2021). Vulnerability mapping can help guide flood plain zoning which like other non-structural flood control measures, which in the view of are usually given less attention by environmental managers (Ogbonna et al., 2015). From the flood risk management point of view, flood risk mapping is a crucial factor. Flood mapping is limited to flood-prone hazard mapping (Safaripour, et al., 2012). Flood risk is the combination of the likelihood of a flood occurring and its adverse outcomes (Ugonna, 2016). Flood risk is the product of the flood hazards probability, the vulnerability and the exposure of the environment, people and the economy (Oladokun & Proverbs, 2016). As highlighted by various studies flood risk probability is high in Nigeria, every region is vulnerable to flood (Oladokun & Proverbs, 2016; Ugonna, 2016; Ifiok et al., 2022; Danhassan et al., 2023).

Environmental risk related to flood event requires its risk assessment which is discussed based on hazard, vulnerability and exposure. The adoption of Geographic Information System (GIS) and Remote System (RS) in the assessment of flood vulnerability is among the leading techniques and can be utilized at various levels (Afolabi et al., 2022). All the flood risk management activities can be achieved with GIS and RS techniques (Ebert and Kerle, 2008; Panagiota et al. 2011) and the technique is efficient in flood vulnerability modeling (mapping), flood risk management planning and development of mechanism of overcoming flood challenges (Otokiti et al 2019). Using various environmental attributes combined in the GIS techniques environment, the present study assesses the environmental risk of Abia state, Nigeria with specific focus on flood event.

Materials and Methods

Study Area

The study area is Abia State, Nigeria. Abia State lies between latitude 50 00'0" N and 50 40'0" N and longitude 7020'0" E and 80 00'0" E (Figure 1). The aborigines of the town are the Ngwa people and they are mostly Christians (Chigbu, 2011). The capital is Umuahia and the major commercial city is Aba. The state is statutorily divided into 3 senatorial zones and has 17 Local Government Areas (LGAs). The capital is Umuahia and the major commercial city is Aba. It's also the 5th most industrialized state in the country, and has the 4th highest index of human development in the country (Nwoko, 2013). Abia State experiences intense rainfall especially in the rainy or wet season. Rainfall is present all year and with and annual total of 2000mm-2300mm, with monthly average of about 180mm (Nwoko, 2013). Temperature experienced in the region is very high with an average daily temperature of about 28oC in the dry season and about 24oC in the wet season. The study area has low temperature range (Nwoko, 2013).

Sources of Data

This study employed the use of both primary and secondary data.

i Landuse map of Abia State acquired from the landsat imagery of 30m x 30m
ii Drainage Network, Road Network, Communities location and Soil map extracted from the topographic map of 1: 100,000 of the study area.
iii Population data of 2016 of the communities from Abia state (NPC, 2016).
iv Topographic guide of the investigation zone from Surveyor General's Office, Ministry of Lands and SurveyLandsat symbolism of 30 m x 30m of 2015 got from the US Geological Survey.

Geo-Information and Vulnerability Map Generation

The imagery of Abia state and topographical map were geo-referenced to world coordinate system (WGS 84) in ArcGIS 9.3 (Figure 2). From the imagery, landuse map of the study area was acquired while drainage network, road network and communities imitative from topographical map. Soil texture map of Abia state was also geo-referenced to WGS 84.
Vulnerability Criteria: This study made use of ranking methods of the vulnerability factors which is embedded in Analytical Hierarchy Process (AHP) proposed by Saaty (1980). AHP is a multi-criteria basic leadership method, which gives a methodical way to deal with evaluating and incorporating the effects of different variables, including a few dimensions of reliant or autonomous, subjective just as quantitative data (Bapalu and Sinha, 2006; Berezi, 2019). Ranking method was adopted because the criterion weights are usually determined in the consultation process with

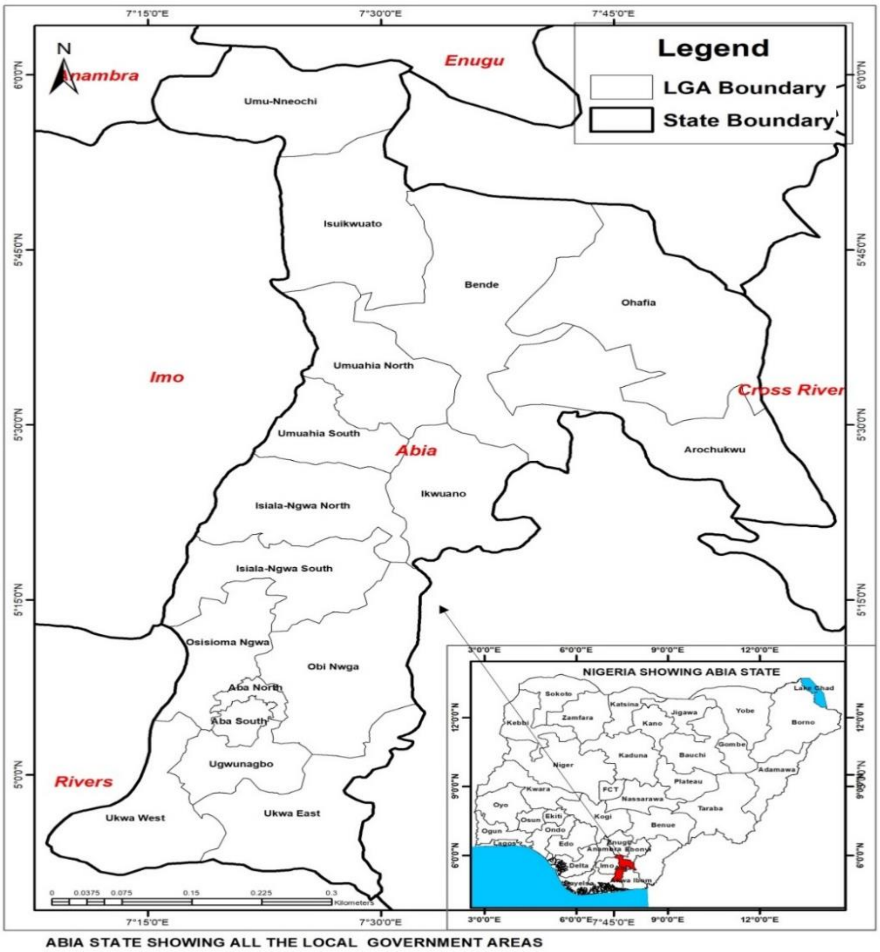

Figure 1: Overview of the Study Area

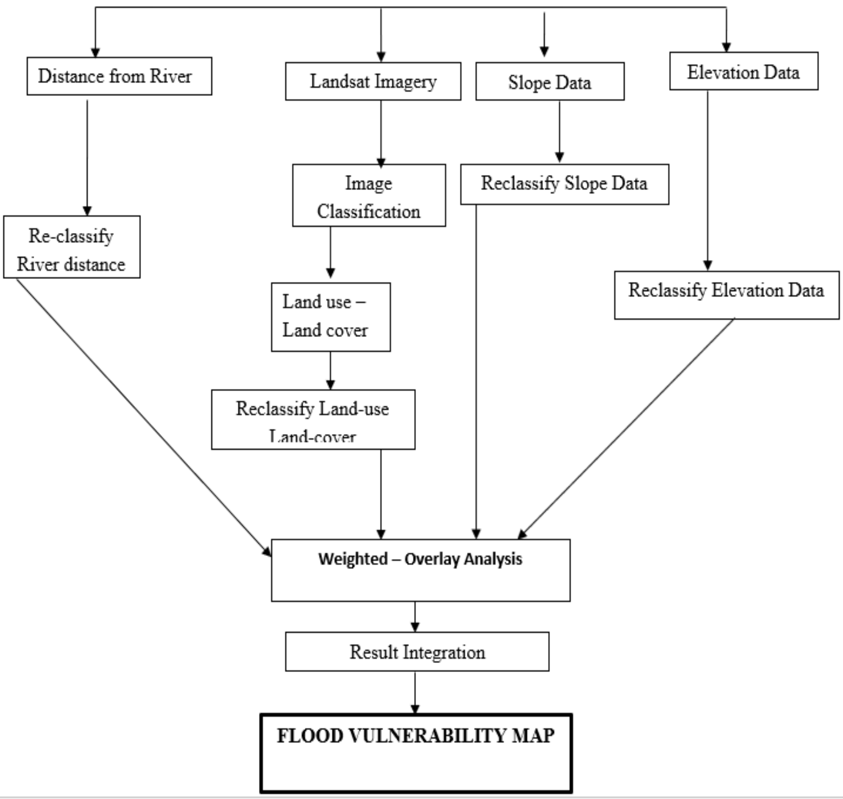

Figure 2: Flood Vulnerability Map Generation Procedure

choice or decision makers which resulted in ratio value assigned to every criterion map (Lawal et al., 2011). In positioning strategy, each measure under thought is positioned in the request of the leader's inclination. To create rule esteems for every assessment unit, each factor was weighted by the evaluated essentialness for causing flood.

i Landuse Map of Abia state: The geo-referenced Landsat imagery was exported to Idrisi Selva for the generation of landuse map of Abia state. Supervised classification technique was adopted with the use of MAXLIKE (Maximum Likelihood Algorithm) module to generate the landuse/land cover types in the area. The area in square kilometer of each landuse type was calculated. The landuse type was converted to vector using Feature to Polygon in ArcGIS environment. The landuse identified were thick vegetation, sparse vegetation, developing area, built up area and water body.

ii Proximity to river channels (Drainage): The drainage network which determines the proximity to river channels and communities were mapped from the topographical map. These geographic features were digitized and captured as vector data in ArcGIS 10.

iii Elevation Map of Abia state: The elevation map was derived from the height above the mean sea level directly from the Google earth image. A 10 x 10 grid system covering Abia state was created in ArcGIS 9.3 and imported into Google earth interface. The latitude, longitude and height in meters at the center of each grid was recorded and input in Microsoft Excel 2007 Version. The latitude, longitude and height of each point were then imported to ArcGIS 9.3 and were used to generate the elevation map through interpolation method.

The landuse, proximity to river channels (drainage) and elevation maps were reclassified into high vulnerability, moderate vulnerability, low vulnerability and no vulnerability.

i Reclassification based on Landuse types: Four (4) types of terrain were observed in relation to their distance to the rivers. In terms of landuse map, the thick vegetation was reclassified to low vulnerability, farmland/sparse vegetation to moderate vulnerability while built up area and water bodies as high vulnerability.

ii Reclassification based on drainage network: In terms of drainage network, the communities were rated based on their proximity to rivers in the study area. Buffering method was used whereby zones of influence were generated as rings of 500 meters, 1000 meters and 1500 meters from the rivers. The ring of 500m was regarded as high vulnerability, 1000m as moderate vulnerability and 1500m as low vulnerability (Mmom and Ayakpo, 2014).

iii Reclassification based on elevation: The elevation map was also reclassified as follows 1.6m-4.6m to high vulnerability, 4.7m-7.6m to moderate vulnerability and above 7.7m to low vulnerability.

The vulnerabilities levels were assigned values 3, 2, 1 to high vulnerability, moderate vulnerability and low vulnerability respectively by applying the ranking method to the factors. Using these values, the landuse vulnerability map, drainage network vulnerability map, soil texture vulnerability and elevation vulnerability map were overlaid in ArcGIS 9.3 with the use of UNION MODULE. Reclassification method was also applied to have very high vulnerability, high vulnerability, moderate vulnerability, low vulnerability and very low vulnerability. The output of this map was regarded as the flood vulnerability map of Abia state considering the landuse, proximity to river channels (drainage network), elevation and soil texture maps of the area. Spatial query in ArcGIS 9.3 was used to determine the vulnerability levels that each community fell into and also used to determine the spatial extent of each vulnerability level.

Result and Discussion

The elevation map was derived from the Digital Elevation Model (DEM) from USGS. The map of Abia State was overlay and clip from the DEM using IDW interpolation technique in Arc GIS 10.8 software. Base on elevation, 46.94% of Abia State is highly vulnerable to flooding and this covers an area extent of 2250.98 sq.km while only 6.47% of the area is lowly vulnerable to flooding based on elevation (Table 1 and Figure 3). The drainage network and drainage vulnerability map of the study area are presented in Table 2 and Figure 4. The results showed that the buffer of 500m from the rivers (high vulnerability) covered a spatial extent of 1913.96 km^2; the buffer of 1000m (moderate vulnerability) covered 1709.87 km^2 while the buffer of 1500m (low vulnerability) covered a spatial extent of 1171.91 km^2. The slope of Abia State was analysed and the outcome was presented in Table 3 and Figure 5. The outcome revealed that slope at 0 to 0.872m was ranked high vulnerability, 0.88 to 2.30m as moderate vulnerability while slope of 2.31 to 9.95 was low vulnerability. The spatial extent covered by high vulnerability based on elevation was 112.20 km^2 (25.07%); moderate vulnerability had 300.17 km^2 (67.06%) while low vulnerability had 35.22 km^2 (7.87%).

Landsat Imagery from USGS 30m by 30m Resolution (Path: 188, Row: 056) was used in the land-use classification using supervised classification technique. The result shows that based on land-use characteristics, only 18.5% of the area is highly vulnerable to flood. On the other hand, 42.7% and 38.8% are moderately and low vulnerable respectively (Table 4 and Figure 6). The built-up area was regarded as high vulnerability due to the fact that presence of hard surfaces can prevent easy infiltration and thereby

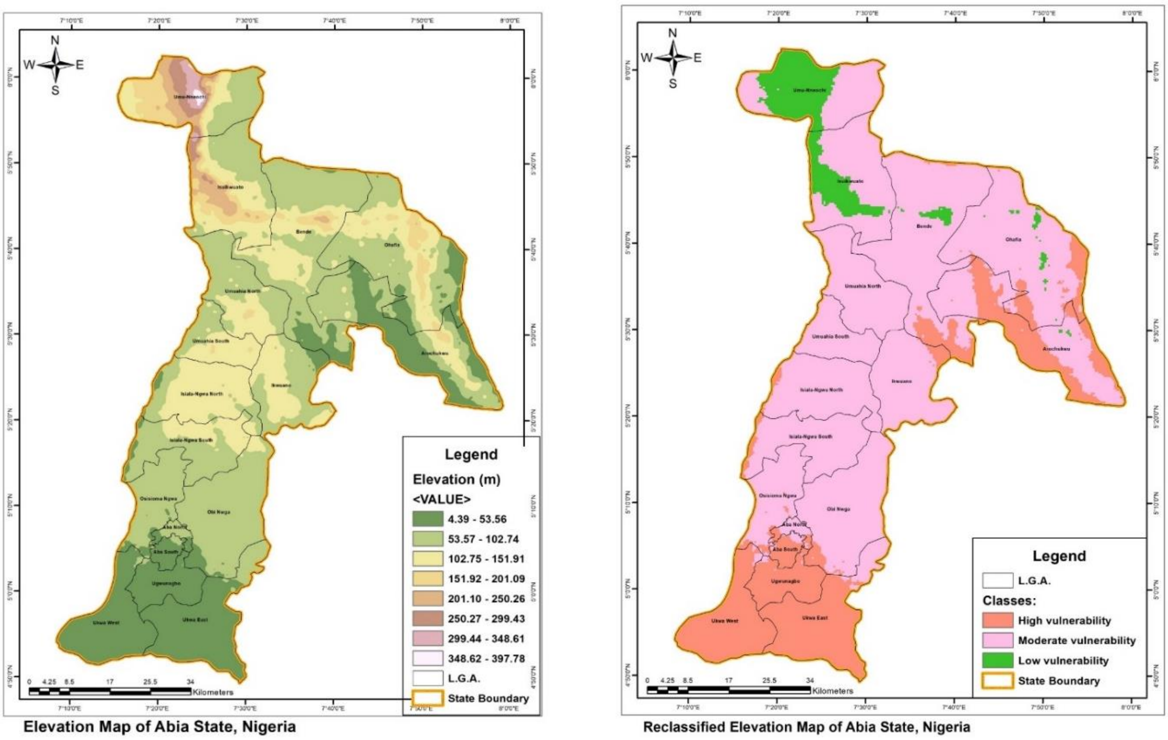

Figure 3: Elevation Map and Reclassification Elevation Map of Abia State

Table 1: Elevation Data of Abia State, Nigeria

Elevation (m)	Spatial Extent (km2)	Percentage (%)	Vulnerability values	Vulnerability level
3.43 - 53.43	2250.98	46.94	3	High vulnerability
53.44 - 250.26	2234.43	46.59	2	Moderate vulnerability
250.27 - 397.38	310.33	6.47	1	Low vulnerability
TOTAL	**4795.74**	**100.00**		

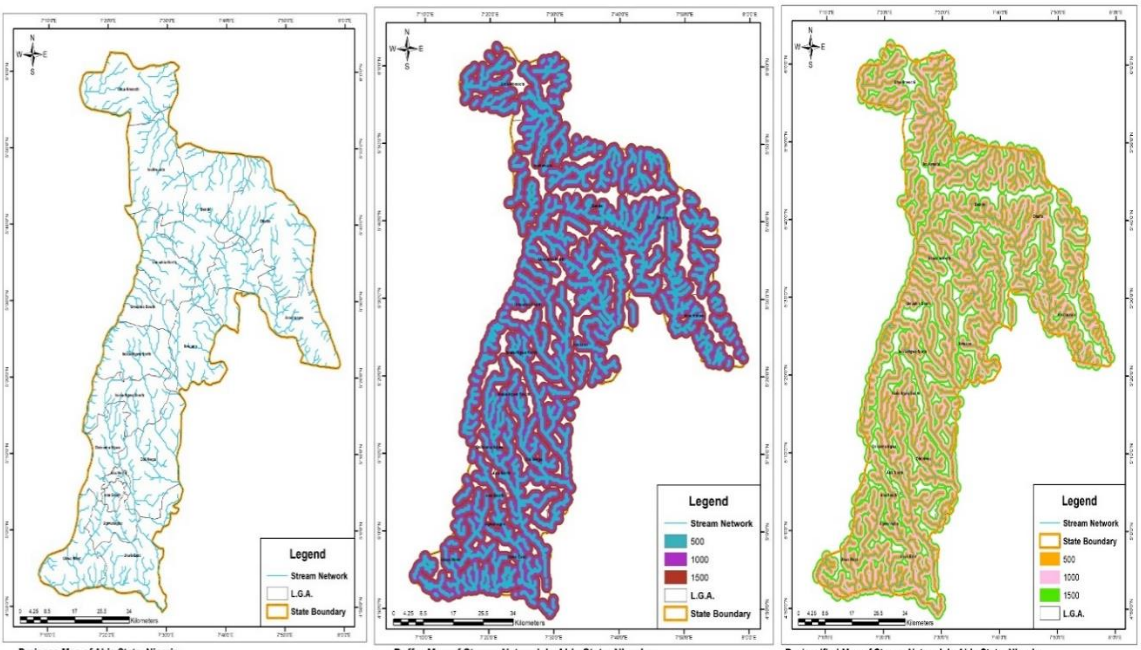

Figure 4: Drainage Map, Stream Network and Reclassification of Stream Network

Table 2: Drainage Network and Drainage Vulnerability

Proximity (m)	spatial extent (km2)	Percentage (%)	Vulnerability values	vulnerability level
500	1913.96	39.91	3	High vulnerability
1000	1709.87	35.65	2	Moderate vulnerability
1500	1171.91	24.44	1	Low vulnerability
TOTAL	**4795.74**	**100.00**		

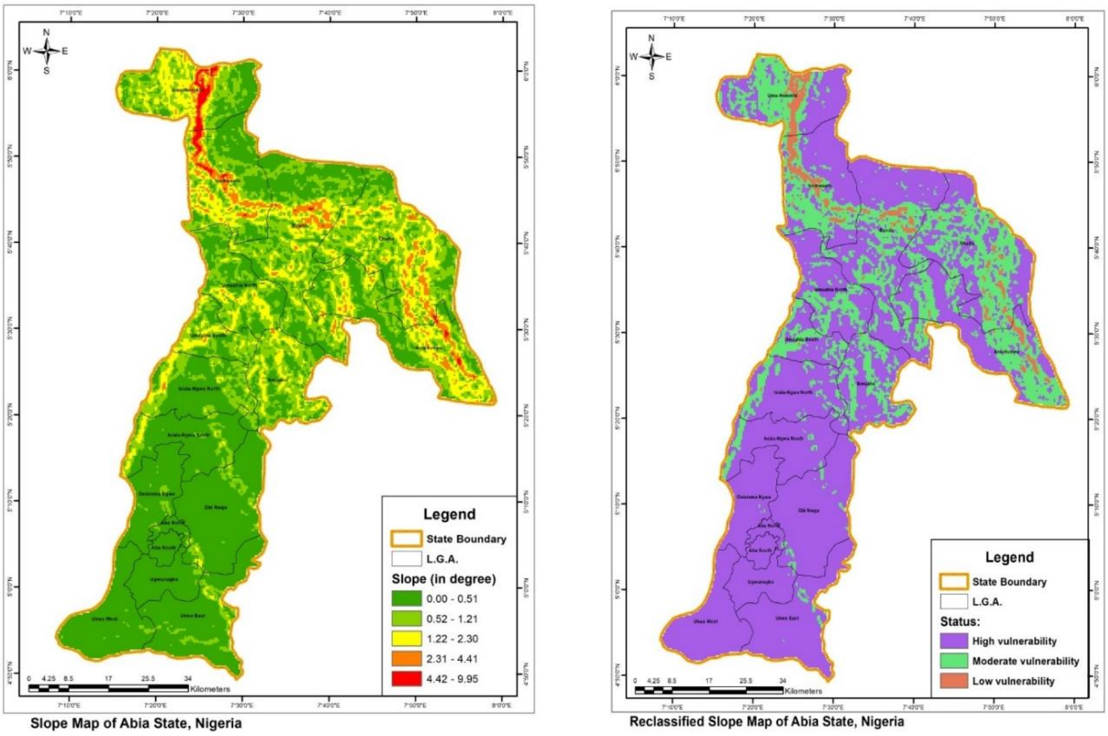

Figure 5: Slope Map and Reclassification of Slope Map of Abia State

Table 3: Slope Details of Abia State

Slope	Spatial Extent (km^2)	Percentage (%)	Vulnerability Values	Vulnerability Level
0 - 0.872	3401.44	70.93	3	High vulnerability
0.88 -2.30	1266.14	26.40	2	Moderate vulnerability
2.31 - 9.95	128.16	2.67	1	Low vulnerability
TOTAL	**4795.74**	**100.00**		

enhancing higher runoff which can easily cause flood (Berezi et al., 2019).

Changes in land use due to urbanization increases flood susceptibility (Kaspersen et al., 2015) as urbanization is largely associated with the removal of soil and vegetation and these are important factors for limiting surface runoff (Adeoye, 2012; Pradhan-salike & Pokharel, 2017). The outcome on elevation showed similarity with that of Happy et al. (2014), and Berezie et al. (2019) which was able to establish the vulnerability level due to elevation of their study area.

Integrating all the parameters, the final vulnerability map was produces which indicates areas with high, moderate and low vulnerability status to flooding (Table 5 and Figure 7). In all, 33.21% of Abia State was observed to be highly vulnerable while 43% and 23.6% were moderate and low vulnerable. The high vulnerable area cut across communities in Ukwa West, Ukwa East, Aba South and Ugwunagbo local government areas. Moderately vulnerable areas were found in communities along northern part of Aba North, Osisioma Ngwa, Isiala Ngwa North/South, Obingwa, Umuahia North/South and Ohafia. Low flood vulnerable areas were basically captured in Ukwa West, Ukwa East, Aba South and Ugwunagbo local

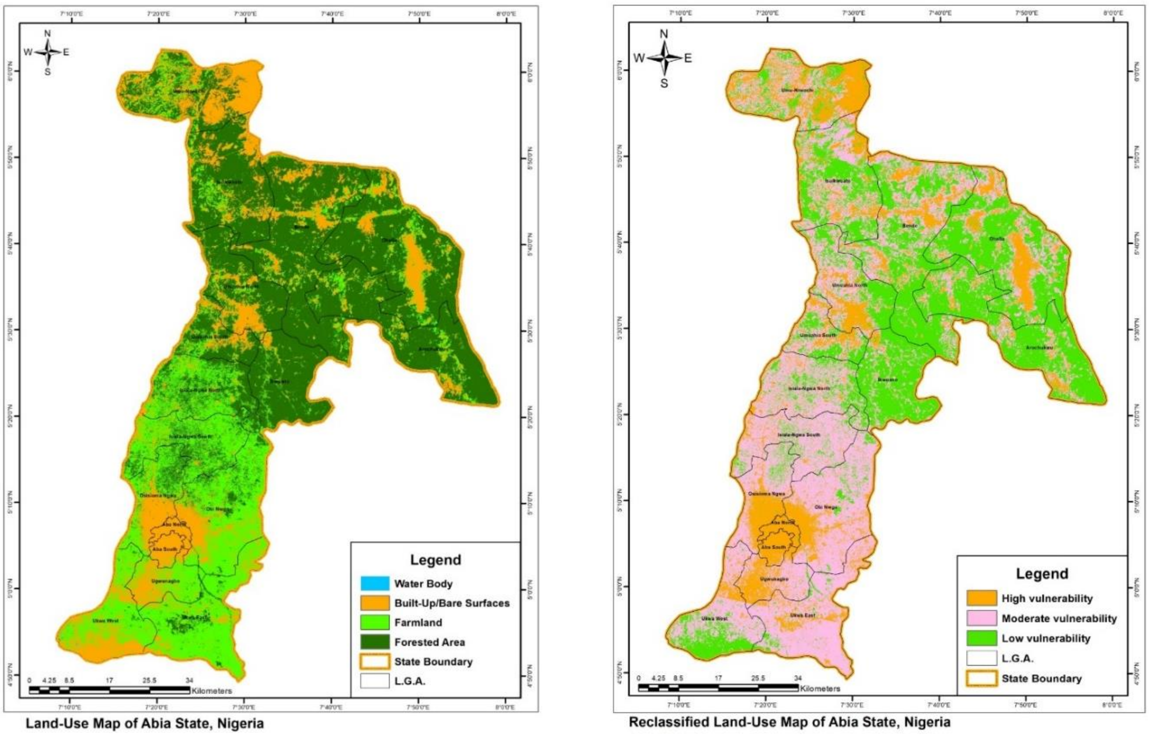

Figure 6: Land-use Map and Reclassification Map of Abia State

Table 4: Table Land-Use Data of Abia State, Nigeria

Land-Use Type	spatial extent (km2)	Percentage (%)	Vulnerability values	vulnerability level
Built-Up/Bare Surfaces and water bodies	887.17	18.50	3	High vulnerability
Farmland	2048.74	42.72	2	Moderate vulnerability
Forest Area	1859.83	38.78	1	Low vulnerability
TOTAL	**4795.74**	**100.00**		

government areas. Moderately vulnerable areas were found in communities along northern part of Aba North, Osisioma Ngwa, Isiala Ngwa North/South, Obingwa, Umuahia North/South and Ohafia. Low flood vulnerable areas were basically captured in communities around Umunneochi, Isikwuato and part of Bende local government area. The outcome indicated that environmental domains such as slope, elevation, land-use and proximity to stream or river when combined are capable of deducing the vulnerability of an area. The outcome is similar to those reported by Chukwuma et al. (2021), Bello and Ogedegbe (2015), Orimoogunje et al., 2016 and Umar and Gray (2022).

Conclusion and Recommendations

The assessment of environmental vulnerability to flooding in Abia State highlights the critical role of climate change and urbanization in exacerbating disaster risks. The integration of GIS and RS techniques enabled the identification of high-risk zones, providing a valuable tool for urban planners and policymakers. Findings reveal that nearly one-third of the study area is highly vulnerable to flooding, which calls for immediate interventions. Effective flood risk management should prioritize high-vulnerability areas while considering adaptive strategies that mitigate environmental impacts. Urban planning, community engagement, and infrastructural upgrades are essential to reduce flood exposure and enhance disaster resilience.

Recommendations:

i Implement robust flood management policies that integrate climate adaptation strategies to mitigate risks in high-vulnerability areas.

ii Enhance urban planning frameworks to address inadequate drainage systems and reduce surface runoff, particularly in built-up areas.

iii Develop early warning systems leveraging GIS and RS technologies to monitor flood-prone zones and issue timely alerts.

iv Promote public awareness campaigns to educate residents about flood risks and encourage community participation in disaster risk reduction

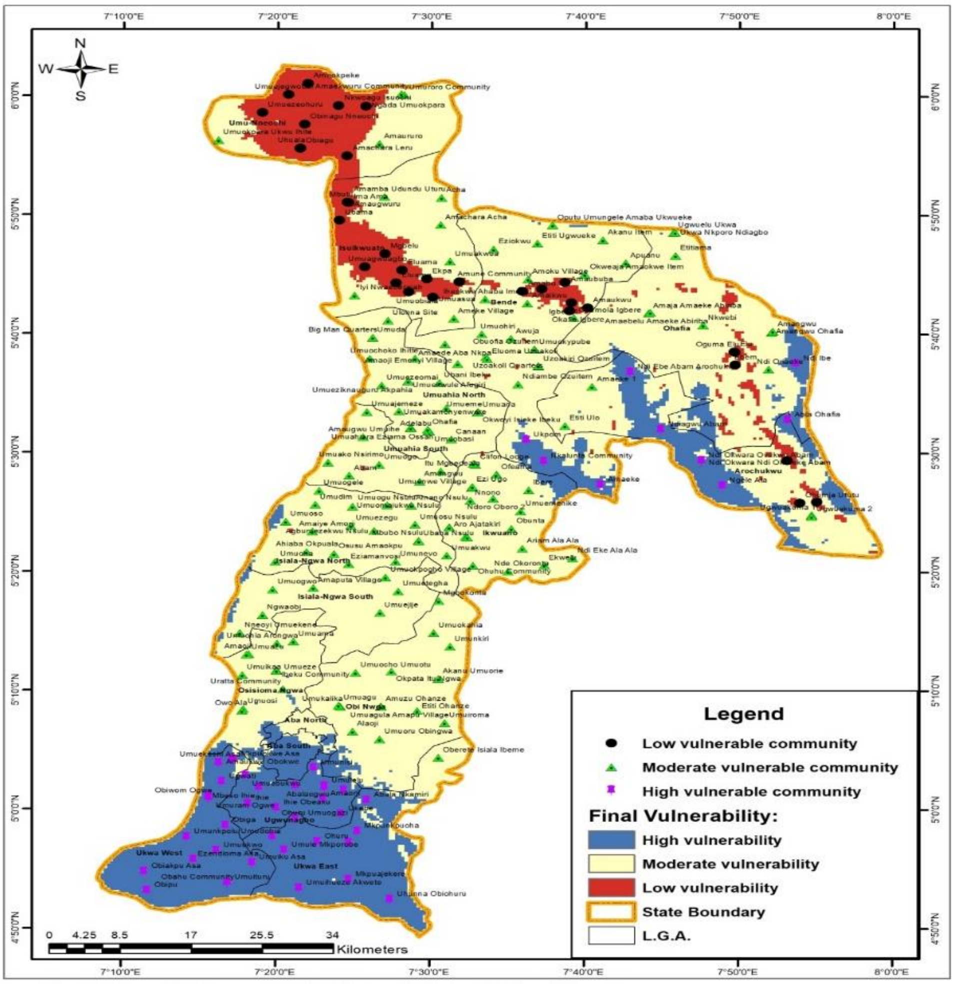

Figure 7: Flood Vulnerability Map of Abia State

Table 5: Vulnerability Details of Abia State

Spatial Extent (km2)	Percentage (%)	Vulnerability Values	Vulnerability Level
1592.67	33.21	3	High vulnerability
2074.64	43.26	2	Moderate vulnerability
1128.44	23.53	1	Low vulnerability
4795.74			

efforts.

v. Strengthen interagency collaboration between environmental managers, urban planners, and local communities to develop sustainable flood mitigation practices.

vi. Conduct periodic assessments and updates of vulnerability maps to accommodate changes in land use, urbanization, and climate patterns.

Declaration of Competing Interest

The author declares no competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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