



A GIS Based Flood Vulnerability Assessment of Abia State, Nigeria.

by

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Abstract

This paper assessed flood vulnerability in Abia State of Nigeria using Geographic Information System (GIS) techniques. The specific objectives included the creation of GIS data base; operationalization and modeling of identified flood vulnerability components; and, the generation of composite flood vulnerability map of the study area. In the study, vulnerability was mapped as a function of exposure, sensitivity and adaptive capacity, using GIS technology. Constituents of each of the three components of vulnerability were identified, weighted and combined using the single output map algebra of the spatial analyst tools extension in Arc map 9.2 environments to create three surfaces which were then combined in the same way to generate the final flood vulnerability layer. The final map was then zoned into high, moderate and low vulnerability classes. The results indicated that the areas of high vulnerability to flood occupied 37.33% of the study area and were found in the north and south central parts of the state. The moderate vulnerability areas covered 35.75% and were found in the central, southern and north east areas; while areas with low vulnerability to flood covered 26.94% of the study area and were found around the south and south central parts. It was recommended from the study that a comprehensive plan involving multi-hazard risk assessment is required for mapping out vulnerability hot spot areas. This will help authorities and stakeholders to steer development towards sustainability.

Key Word: GIS, Flood, vulnerability, Abia State, Nigeria.

1. Introduction

Flood vulnerability assessment has become an essential tool in society's efforts to lessen the impact of disaster, as it is helpful in all levels of disaster management (Aziz, Nitin, Kusanagi, 2005; Udoh and Nkan 2015). Plans on flood hazard and vulnerability in recent times have increased because of growing recognition of the danger and the need to prepare for and manage the effects of flood hazards. Vulnerability refers to the degree to which biophysical, biological and socioeconomic systems are susceptible to and able to cope with the adverse effects of hazards (Schneider, et al, 2007). International Panel for Climate Change (IPCC) (2001), and, Coburn, Spence and Promonis (1994), also see vulnerability as the measure of how the elements at risk in a landscape would be damaged if they were exposed to the same level of hazards. It is being prone to or susceptible to damage or injury (Blaikie, Cannon, Davies and Wisner, 2004) and involves a combination of different factors that determine the degree to which someone's life and livelihood is put at risk by an identifiable event in nature or society. IPCC (2001) conceptualized vulnerability as a function of character, magnitude and rate of a hazard being exposed, its sensitivity and its adaptive capacity. This can be expressed as:

$$\text{Vulnerability} = f(\text{exposure} + \text{sensitivity} + \text{adaptive capacity}) .$$

The IPCC report upon which this definition is based has now become the framework for vulnerability mapping (Yussuf and Francisco, 2009). Exposure is seen as the nature and degree which a system is exposed to hazards; sensitivity as the degree on which a system is affected either adversely or beneficially by the hazard while adaptive capacity on the other hand is the ability of a system to adjust to the hazard, to modify and moderate the potential damage from it, to take advantage of opportunities or to cope with its consequences (IPCC, 2001)

Edward, Gustafsson and Landenmark, (2007) enumerated the various benefits of vulnerability assessment and mapping which are summarized as follows: it provides information that leads to disaster impact reduction through safety and environmentally conscious land use planning and management; improves the ability of policy makers to promote disaster reduction thereby protecting inhabitants and their livelihood, the natural environment, infrastructure and property; gives the precise location of site where people, the natural environment or property is at risk due to potentially catastrophic events that could result in death, injury, pollution or other destructions. Vulnerability maps also allow for improved communication about risk and what it threatens; and, allow for better visual presentations and

understanding of risk and vulnerability so that decision makers and stakeholders can see where resources are needed for protection of these areas.

Geographic Information System (GIS) has become useful in vulnerability mapping because of its capacity to accomplish tasks which was difficult to perform using traditional methods. As a versatile tool for database inventory, preparations and subsequent cartographic and spatial analysis of geographic database, GIS can be used in flood-forecasting and floodwater movements. It has proved to be a robust, dynamic and reliable technology for providing geospatial information and making the right decisions in solving flood related problems (Green, 2002). GIS has also proved useful in flood vulnerability assessment and mapping as it offers unsurpassed widerange of capabilities and opportunities. A widerange of studies have been carried out utilizing this technology in flood vulnerability assessment in different parts of the word. These include Ngie (2012) in Johannesburg, South Africa; Ouma and Ttaeishie (2014) Eldoret Municipality in Kenya; Yalcin and Akyurek (2004) in Bartın Basin in the West of Black Sea Region ; and, Peck, Kaimaha and Simonovic (2009) in the Upper Thames watershed located in South Western Ontario, Canada.

In the light of the foregoing, the main objective of the study was to map flood vulnerability in Abia State of Nigeria using the framework set by the IPCC (2001) and utilized by Yusuf and Francisco (2009). Thus, vulnerability is mapped as a function of exposure, sensitivity and adaptive capacity, using GIS and remote sensing technologies.

2. The Study Area

Abia State is situated in South Eastern Nigeria and lies between latitudes 4° 45'N and 6°00'N of the Equator and Longitudes 7°0'E and 8° 09'E of Greenwich meridian (Figure 1). The area covers about 5420km² with a total population of 31,243.203 people and a population density of 57.64 person/km² based on a projected population of 2006 (NPC, 2007). Mean annual rainfall over the area decreases gradually from 2200mm – 1900mm south to North. The hottest period is between January and March with temperature of above 27⁰C (dry season starts from November to March). The relative humidity (remain at an average of 70% to 80%) is usually high throughout the year. The area is noted for its low-lying flood plains and rain forest. It is drained by a number of rivers and streams with Qua Iboe River being the most significant. The area has very high agricultural potentials and is rich in crude oil and gas, oil palm trees and many other natural resources.

3. Materials and methods

The data sets in the study were extracted from various sources. The political boundaries of 17 local government areas were derived from the administrative map of Abia State on a scale of 1:150,000 obtained from Abia State Town Planning Authority. Soil association, vegetation and drainage maps used in the vulnerability modeling were also obtained from the same source. Demographic and socio economic parameters were extracted from National Population and United Nations Development Programme reports (NPC,2006 ; UNDP,2006). Elevation, aspect and aspect data with a 30m x 30m resolution were extracted from the digital elevation model (DEM) of the state obtained from the United States Geological Survey. Field observation provided the inventory of the distribution of flood locations in the study area.

The political map of the state was scanned into a GIS environment, geo-referenced and digitized. The attribute table of each L.G.A. digitized as polygon was used to link the datasets to create and generate the base maps used for the GIS analysis. The base maps were converted from vector based shapefiles to grids that made it possible to use all data sets for further analysis and modeling in the GIS environment..

The flood vulnerability of the study area was conceptualized in a GIS environment as a combination of Exposure, sensitivity and Adaptive capacity map layers. The three surfaces were generated and combined using Arcmap 9.2 spatial analyst function. The exposure surface was generated using identified exposure component sources - elevation, aspect, slope, and sea level rise and soil association. DEM yielded data for elevation, aspect and slope; while sea level rise was modeled as a function of distance from water bodies. Human and Ecological sensitivity layer was generated from the combination of 2006-2014 projected population and land use /land cover of the study area; while, adaptive or coping capacity layer was derived from the Human Development Index (HDI) and Human Poverty Index (HPI) extracted from UNDP Report (2006). It should be noted that while exposure and sensitivity surfaces were modeled as directly proportional to flood vulnerability, adaptive capacity had a negative relationship. Hence, a high exposure and sensitivity means high vulnerability to flood. High adaptive capacity revealed low vulnerability to flood and vice versa. That is, areas with high adaptive capacity had low flood vulnerability while areas with low adaptive capacity had high flood vulnerability

The three surfaces (presented in Figures 1 – 3.) were weighted and combined, using the single output map algebra of the spatial analyst tools extension, a multi-criteria technique in Arc map 9.2 environment to generate and produce a final (single) flood vulnerability surface. It was zoned into highly vulnerable, moderately vulnerable and lowly vulnerable classes as presented in Table 1 and Figure 4.

4. Results and Discussion

The study utilized the GIS environment to generate and combine, exposure, sensitivity and adaptive capacity datasets to create flood vulnerability map for Abia State of Nigeria. Figure 1-3 show the spatial pattern of the vulnerability components in the state. In Figure 1 which shows the exposure layer, the high exposure areas were found to occur in the northern part of the state including parts of Umunneochi, Isiukwuato, Ohafia, Arochukwu, Bende and Umuahia, and Aba (North and South) LGAs. Moderate exposure areas were predominant in the north east, north west, central and southern parts of the state. Low exposure areas on the other hand were found predominantly in the southern parts of the state including parts of Osisioma, Isialanwa, Ukwa West and Obingwa LGAs.

Sensitivity layer is displayed in Figure 2 and it shows that it is high in the northern part of the state, in the central part (Aba – North and South), and, in south west (Ukwa West). Moderate sensitivity areas dominated the central part of the state, and, were found in the north east scattered among the high sensitivity areas. Low sensitivity areas could be seen north and south of the medium sensitivity areas found in the central portion of the study area. Adaptive capacity layer shown in Figure 3 indicated that this component was high in the north east and north west LGAs, moderate in north central, and low in the central and southern areas.

The final flood vulnerability layer (Figure 4) shows that the High vulnerability areas were concentrated in 13 LGAs- Umunneochi, Isiukwuato, Ohafia, Arochukwu, Bende, Umuahia North, Osisioma, Aba North and South, Ugwunagbo, Ukwa East and West, and Obingwa. Moderate impacts were found in 9 LGAs- Ohafia, Arochukwu, Bende, Umuahia North and South, Isialangwa North and South, Obingwa and Ukwa West. The low vulnerability classes to were 10 LGAs – located in Ikwuano, Umuahia South, Isialangwa North and South, Osisioma, Aba North and South, Obingwa, Ukwa East and West respectively. The analysis of the flood vulnerability surface indicated that areas of high vulnerability to flood as 37.33% were found in the north and south central part of the state. The moderate

vulnerability areas covered 35.75% and were found in the central, southern and north east; while low vulnerability areas which covered 26.94% of the study area were found around the south and south central parts.

Table 1- Areal extent of final flood vulnerability classes

Vulnerability classes	Area (in km ²)	%
Highly vulnerable	2022.83	37.33
Moderately vulnerable	1936.71	35.73
Lowly vulnerable	1460.46	26.94
Total	5,420.00	100.00

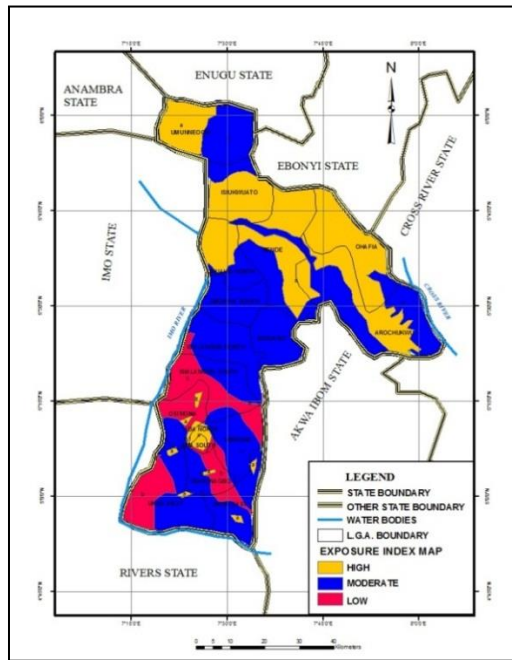


Fig. 1: Exposure layer of the study area

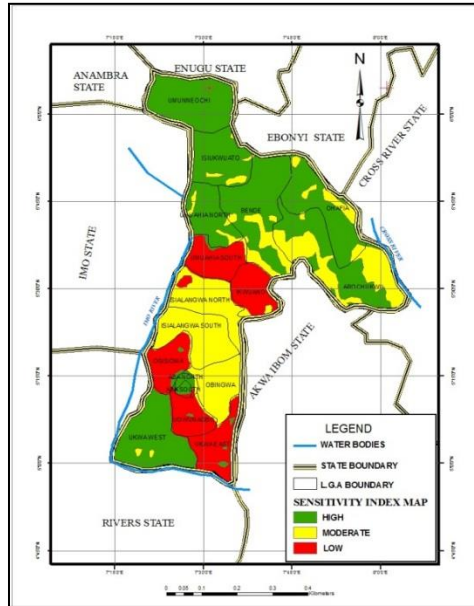


Fig. 2: Sensitivity layer of the study area

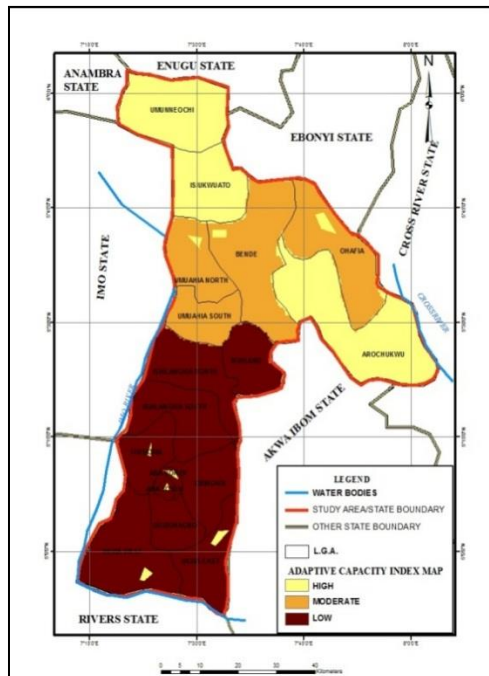


Fig. 3: Adaptive capacity layer of the study area

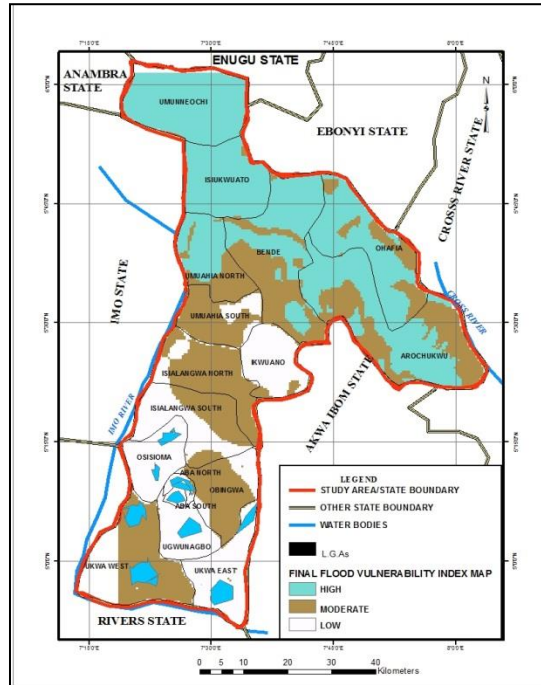


Fig. 3: Final vulnerability layer of the study area

The spatial pattern of the composite flood vulnerability of the study area was not surprising as Exposure and Sensitivity were generally high in the northern parts of the state than in the south. The general exception to this was found around Aba; a major commercial nerve center of south eastern Nigeria, hence ranking high in sensitivity and overall vulnerability. The assertion that Adaptive Capacity generally moderates vulnerability (Yusuf and Francisco, 2009) could be seen in the north central portion of the study area with its lower total vulnerability than the surrounding areas.

5. Conclusion

The study integrated various data sets to map flood vulnerability components and the final composite flood vulnerability map of the study area. It has revealed the ability of vulnerability maps to communicate information that will enable stakeholders to militate against flooding and its impact in Abia State. In this way, disaster impact reduction can be achieved leading to a better environmental living

condition in the study area. Eastern Nigeria is noted for its susceptibility to erosion, hence there is the need for a comprehensive plan involving multi-hazard risk assessment for mapping out vulnerability hot spot areas. This will help authorities and stakeholders to steer development towards sustainability.

6. References

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