Modelling and Assessment of Flood Vulnerability of Settlements in Owerri West L.G.A in Imo State, Nigeria Using Remote Sensing and GIS

ABSTRACT

Mitigation of impact of flooding is successful only when detailed knowledge of vulnerability of people and facilities to flooding is available. Therefore, in this study, attempt has been made to demarcate the study area into different levels flood vulnerability potential zones using remote sensing and Geographic information system (GIS). It identifies spatial variations in flood vulnerability potential levels with a view of fostering the best approach for flood management. Software used include ArcGIS10.3, ERDAS Imagine and supher11. Data used include ASTER DEM of 30m resolution, LANDSAT imagery of resolution 30m, administrative map of the study area, GPS point locations of communities within the study area and population statistics of the study area. These datasets were populated in GIS window and flood causative factors such as slopes, elevation, land use, proximity to the river, population density, and flow accumulation were extracted, and integrated to demarcate the study area into levels of vulnerability potentials and determine communities and population in different vulnerability categories. The study revealed that 15.729 (5.22%) square kilometers, 232.575 (76.97%) square kilometers, 53.747 (17.79%), square kilometers, and 0.093(0.03 %) square kilometers of the study area are under high vulnerability, moderate vulnerability, low vulnerability. and very low vulnerability potentials respectively. It further revealed that approximately, 7361, 108843, 25153 and 44 number of persons within the study area are respectively residing within these vulnerability zones.

Keywords: vulnerability, Flood Disasters, GIS, Remote sensing

1.0 INTRODUCTION

The rise of average temperature is a globally realized and confirmed phenomenon, and there is a general consensus on the scientific community that this is due to anthropogenic pressures, resulting to the increase in precipitation events severity, as well as duration [1-2]. As a result of extreme climatic condition, the intensity of rainfall has increased tremendously causing floods in many areas and countries worldwide [3]. Floods are one of the most hazardous threats to several communities affecting mainly the economy and wellbeing of the people [4]. Averagely, 231 million people annually, are affected by one natural hazard or the other [5]. Nigeria has witnessed diverse flood events in the past years. Due to the high level of vulnerability couple with lack of adaptability of the people resulting from extreme climatic conditions many lives and properties in Nigeria are at risk of its impacts. Flood is considered to be one the most devastating and frequently occurring disaster within global communities. Impacts of flood disaster on the society and its effect on sustainable development are overwhelming in recent years. Reliable information relating to vulnerability of people and facilities to flooding is invaluable for adequate preparation and mitigation. Flood vulnerability maps provide useful data for estimating levels of vulnerability of people and assets within a given area. Daniela et al [6] reported that accurate flood risk assessment is an important component of flood mitigation in urban areas**.** An Extensive literature about flood conditioning factors has been made known by many researchers [7]. Mitigation of flood disaster can be successful only when detailed knowledge is obtained about the vulnerability of the people, buildings, infrastructure and economic activities in potentially dangerous area [8]. The fundamental cause of river flooding is excess runoff induced by heavy rainfall. This runoff is often obstructed by anthropogenic factors which involve the concentration of developmental activities along the river natural flow path [9]. Changes brought about by uncontrolled urban development in Owerri West have negatively altered hydrological regimes, and exposed open spaces to flood. In recent times Owerri West has been having issues of flooding. With the increasing number of urban dwellers, the number of people and assets vulnerable to flood hazard in Owerri West is increasing such that it has been identified as a serious threat to sustainable development. The frequency of severe flood incidents has increased, necessitating a reliable approach in managing flood risk. As per [10] the current trend and future scenarios of flood risks demand accurate spatial and temporal information on the potential hazards and risks of floods. Integration of remote sensing and GIS has been confirmed as reliable to manage disaster in geospatial domain. Therefore, this study adopted these technologies for assessment of flood vulnerability levels of communities within Owerri west L.G.A. Figure1 below show situations during 2022 flood within the study area.

Fig1 Scenarios created by flood in Owerri west in 2022

(Source; Author’s field investigation)

1.2 Study Area:

Owerri West is a Local Government Area in Imo State, Nigeria with headquarter located in the town of Umuguma. It has an area of 302.144km^2 and geographically, located between latitude 6° 60’ 0"E to 7°3’ 0“E and longitude 5° 21' 0"N to 5°27'0"N Communities in Owerri west include Umuguma, Avu, Okuku, Oforola, Obinze, Nekede, Ihiagwa, Eziobodo, Okolochi, Emeabiam, Irete, Orogwe, Amakohi, etc. it has a population of 101754 based on 2006 population census and a projected population of 141400 in 2022 based on data from national burau of statistics

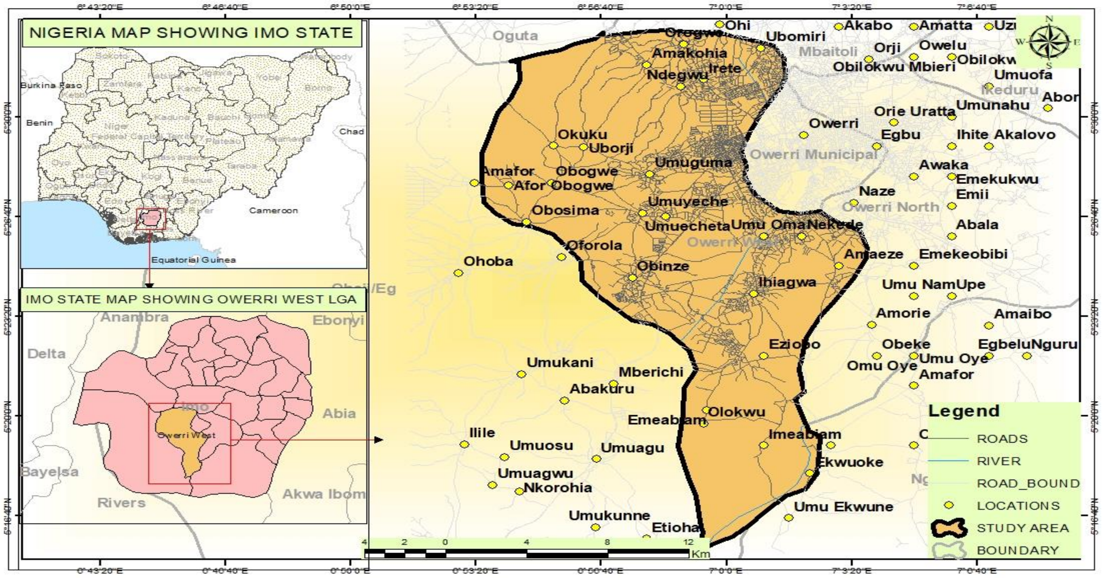


Fig 2 Location Map of Owerri West

2.0. MATERIALS AND METHODS

The data used for this study includes the Advance Spaceborne Thermal Emission radiometer (ASTER DEM) data of 30m resolution. This was used for generation of digital elevation model, drainages slope and flow accumulation maps. Other datasets include Landsat satellite imageries with resolution 30m obtained from Global land cover facility, 2006 breakdown population data and 2022 projected population statistics of Imo state obtain from National Bureau of statistic, administrative map of the study area and ground truthing data. Software used include ArcGIS 10.3, ERDAS Imagine and Sufer11.

2.2. Terrain analysis and Drainage network extraction

Blocks of ASTER GDEM of the study area were populated in ArcGIS 10.3 environment and mosaicked. Progressively the elevation raster was transformed from geographic coordinate system to projected coordinate system (i.e. from GCS-WGS1984 to WGS1984 World Mercator). Using the boundary shape file of the study area, the data was masked to actual boundary limit. Subsequently, the output was used to generate digital elevation model which was categorized into elevation levels using symbology tools and further processed to slope and flow accumulation maps. Since vulnerability of people and facilities largely depend on terrain of their locations in space, the slope and elevation maps were Integrated and reclassified into vulnerability levels based on terrain heights and slope percentage (figure3).

2.2 Vulnerability map based on proximity to the river hydro analysis

Flood intensity all over the world depends on the proximity or the closeness of any location from the main waterbody and the flow accumulation attributes of the watershed in which they are located. Therefore, vulnerability analysis was made using each of these factors. The masked elevation raster was further subjected to void filling and further processed to flow direction and flow accumulation maps. The flow accumulation raster was fundamental for stream network delineation. Progressively vulnerability assessment was carried out based on distance from the water bodies using buffer tool.

2.3 vulnerability map based on Land Use /Land Cover

Empirical researches have shown that exposure to flood depends the land-use/land cover character of an area. For example, location on built up areas are more vulnerable to flood than forest areas due existence of multiple impervious surfaces that promotes overland flow. Landsat satellite imagery covering the study area was pre-processed and land use/land cover map was generated using maximum likelihood supervised classification algorithm in ERDAS Imagine software window. Accuracy assessments was carried out using ground-truth data to ensure that the classified pixels faithfully represent reality. The result was exported to ArcGIS 10.3 and the feature categories were converted to vector layers. Vulnerability assessment was carried based on the hydrological character of each feature class.

2.4 Vulnerability mapping:

Several flood vulnerable maps were first produced using different flood causative factors which include elevation, land use/land cover, flow accumulation, and proximity to river. Selection of these factors was based on quotation frequencies in flood-related publications, expert's opinion, availability of data as well as the authors' knowledge of past flood events in the area being investigated. Each of the factor as a standalone was used to categorize the study area into different levels of vulnerability. Final Flood vulnerability analysis and mapping has been made by overlaying the reclassified maps of all the factors using addition operator and intersect analysis. Final vulnerability level detection and demarcation was based on number of flood indicators identified at various locations (fig7). The map generated was validated by field verification which was conducted multiple times after extensive rainfall.

2.5 Geo-Physical Vulnerability Assessment

In this research geo-physical vulnerability assessment was determined based on location of communities, percentage of the population at l various potential danger. GPS coordinates of communities within the study area and population statistics were used for the assessment. The specific locations of all the settlements were derived by using GPS to obtain the coordinates of each of the locations of the communities. These coordinates were plotted on the vulnerability map. The vulnerability levels of these communities were determined based on their locations on the final vulnerability map. Progressively, the spatial extent (area) covered by each vulnerable category was derived using calculate geometry module of ArcGIS and the metric values (area of landmass) were multiplied with projected population density of 2022 of the study area to estimate the number and percentage of the population at various vulnerable levels.

3.0. RESULTS AND DISCUSSIONS

3.1 Results

The results reveal different flood vulnerability potentials based on four flood inducing factors this is shown in figure3 to 6. The final vulnerability map as shown in figure7 categorized the study area into different vulnerability potential levels. Each level is associated with a specific area in square kilometers. Table1 shows the spatial extent of the various vulnerability potentials in absolute and percentage value and this is corroborated by figure 8 and 9. Colume3 (table1) shows the communities residing at the various vulnerability levels and figure10 portrays population of people residing at each vulnerable zone in percentage and absolute value.

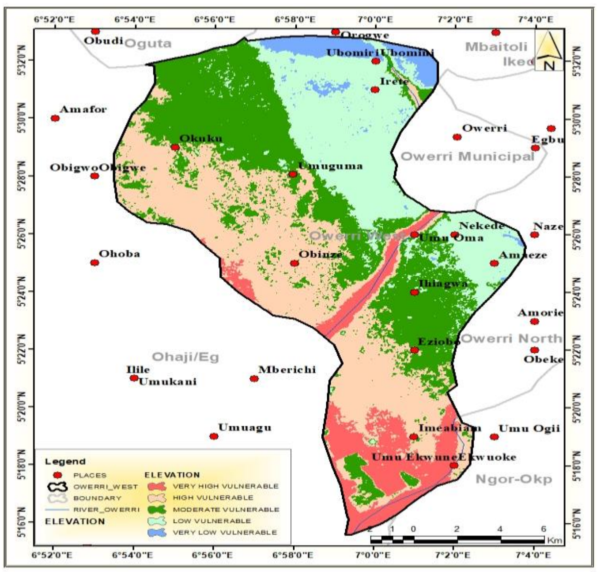


Fig 3 Vulnerability map base on elevation

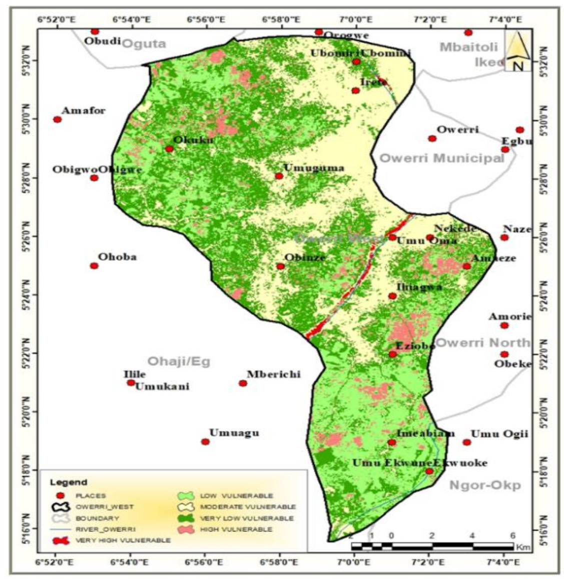


Fig 4 Vulnerability map based on Land use

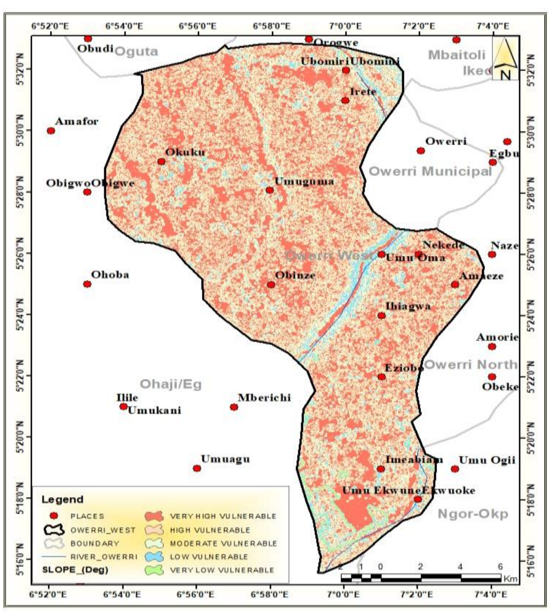


Fig 5 Vulnerability map based on drainage density

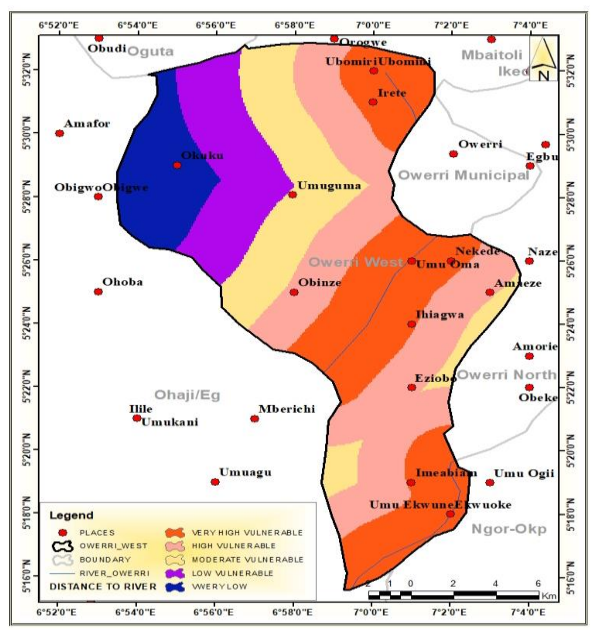


Fig6 Vulnerability map based on proximity to the river

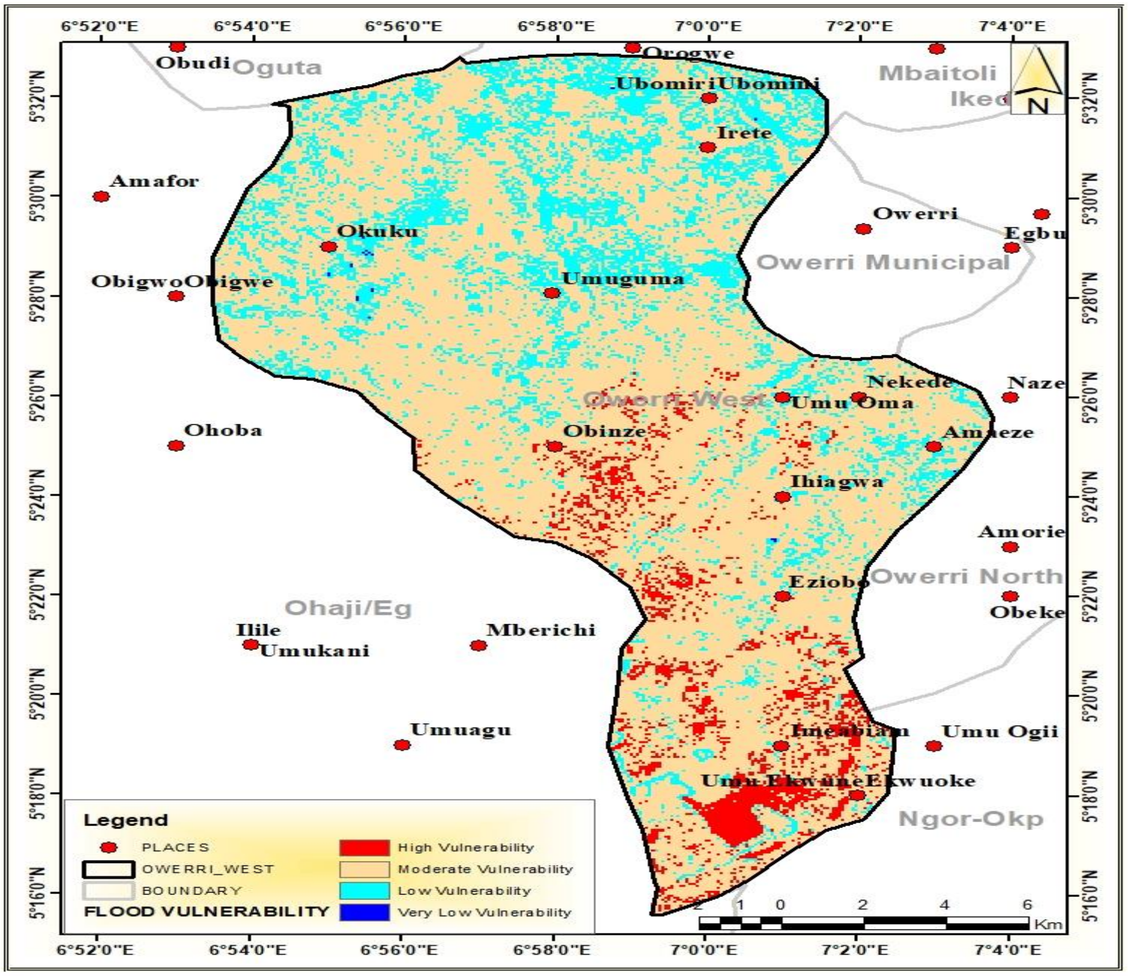
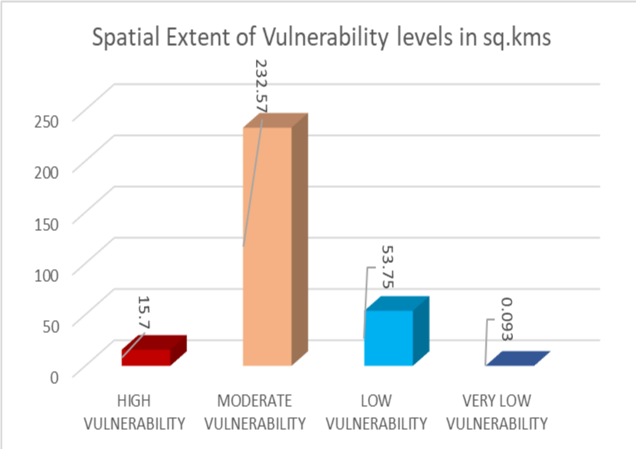


Fig 7 Final Flood vulnerability map of the study area

Table1 Vulnerability Statement of the study area

S/N	**Vulnerability Level**	**communities**	**Spatial Extent (Km2)**	**Percentage (%)**	**Estimated Pop. At Various Vul Levels In 2022**
1	High Vulnerability	Imeabiam, Umuewueme, Obinze etc	15.729	5.22	7360.999
2	Moderate Vulnerability	Ihiagwa , eziobodo, irete, Nekede etc	232.575	76.97	108842.5
3	Low Vulnerability	Okuku, umuguma, Ameze, Ubomiri etc	53.747	17.79	25153
4	Very Low Vulnerability	-- -- -- -- -- -- -- -- -	0.093	0.03	43.52298



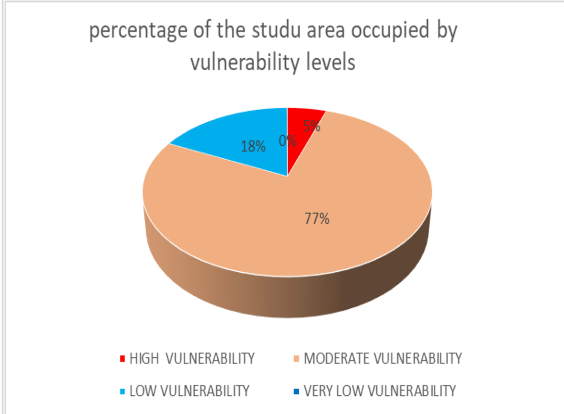


Fig8 Area of land at various vulnerability categories

Fig9 **Percentage of land at various Vulnerability categories**

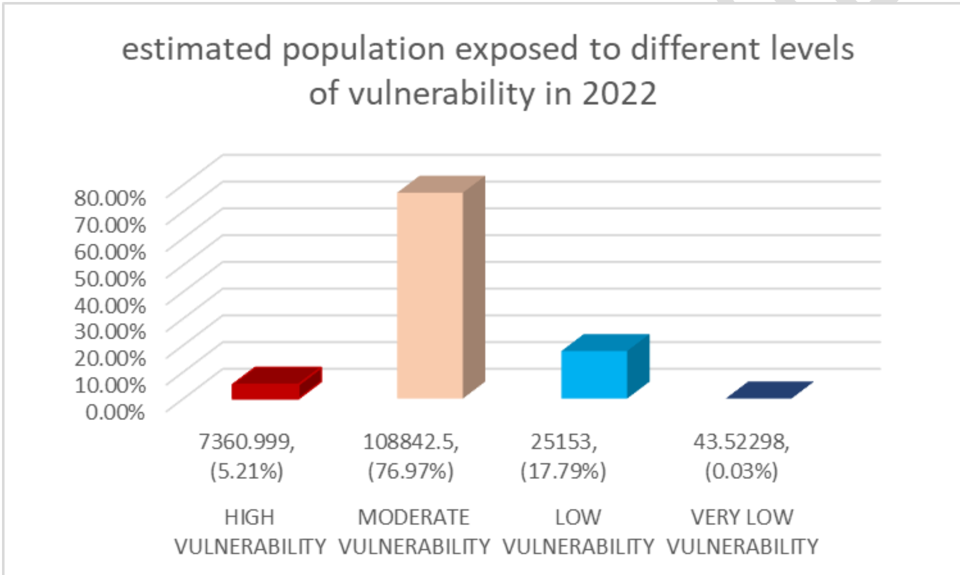


Fig10 Population at various Vulnerability categories in owerri

3.2 Discussion of Result

Figure3 is the Vulnerability map based on elevation. It revealed that Imeabiam and Umuekwueme communities are located in low lying terrain and low elevated areas are considered to be highly prone to flooding. Conversely communities like Irete and Ubommiri are located in high land. Figure4 is the Vulnerability map based on land use. It can be seen that Obinze , Ihiagwa , Irete, Umuoma and Umuguma communities are located in built up areas. In flood modelling, built up areas are considered to be highly vulnerable to flood due to existence of numerous impermeable surfaces that encourage overland flow. Figure5 shows flow accumulation map. Locations of high flow accumulation are characterized as areas of longer inundation time during flooding this is because the terrain cells within these regions are lower than the surrounding neighbors therefore accumulates flows from these cells. Figure6 is the Vulnerability map-based on proximity to the river. It can be seen that communities such as Umuoma, Nekede, Iheagwa, Imeabiam and Umuekwuame are located in close proximity to the river. This attribute exposes them to flooding from over flow from the river. Figure7 is the final vulnerability map obtained by integrating these flood causative factors. Table1 and figure 8 through 10 are the metrics and graphical analysis drawn from the final map, From these models, it can be seen that quantitively high Vulnerability places covered 15.729 (5.22%) square kilometers, moderate Vulnerability areas covered 232.575 (76.97%), low Vulnerability places covered 53.747 (17.79%), square kilometers, and very low vulnerability covered a land space of 0.093(0.03 %) square kilometers of the study area respectively. It further revealed that approximately, 7361, 108843, 25153 and 44 number of persons within the study area are respectively residing within these vulnerability zones.

4.0 **CONCLUSSION**

Conventionally, flood emergency management, both public and private, usually responds to crises rather than being concerned with the fundamental issues of vulnerability and its management and one of the reasons is lack of a reliable approach to model and predict the current impact and future trends respectively. In this study remote sensing and GIS were integrated to demarcate Owerri west into flood vulnerability potential zones, determine spatial extent and communities at each vulnerability levels as well as the population residing within these regions. The map produced was validated through field visitation made after extensive and long duration down pour during the rainy period. The derivatives were further represented using graphs and charts as a tool for emergency planning and mitigation. These are invaluable for flood management within the study area.

3.3. Recommendations

1. The government should encourage maintenance of a green environment and come up with policies and regulations to reduce anthropogenic activities that contributes to climate change activities. For example, there should be discouraging of deforestation and promotion of afforestation.

2. Sensitization programs on flood disaster risk management and mitigation should be initiated and promoted by governmental and non-governmental organization (NGOs).

3. policy makers and all stake holders concerned in disaster management should adopt this reliable technique for disaster management.

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