



(RESEARCH ARTICLE)



## Assessment of flood hazard in Owerri West, Imo State, Nigeria using Analytical Hierarchical Process and Index Based Approach

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### Abstract

This study aimed at an assessment of flood hazard areas in Owerri Imo State, Nigeria using analytical hierarchical process and index-based approach. The study objectives were to: establish the geophysical factors that contribute to flooding in the study area; classify the established geophysical factors according to the level of flood risk; calculate the reliability index of the classified geophysical factors; determine the flood vulnerable areas using analytical hierarchical process and flood hazard index; and to produce a vulnerability index map defining the extent of flooding vulnerability in the study area. The methodology incorporated in this study involved acquisition of remotely sensed imageries of the study area, pre-processing, Image classification, modelling slope, watershed, Drainage Network, flow accumulation, Soil Classification, classification and standardization, pairwise comparison matrix, normalized weighted Matrix, consistency index check and flood hazard index modelling. The study results revealed that In Owerri West, high flood vulnerability occupied 1.54% with an area coverage of 817.78 hectares, moderate flood vulnerability occupied 28.37% with an area coverage of 15031.98 hectares, low flood vulnerability occupied 24.97% with an area coverage of 13228.25 hectares and no flood vulnerability occupied 1.67% with an area coverage of 882.17 hectares. From the results achieved and the experiences gathered, analytical hierarchy process and flood hazard index-based modelling approach is recommended as it is a robust and efficient tool for mapping flood vulnerability while incorporating robust factors that contribute to flood and having a consistency judgement which judges the reliability of the weights of the factors used during modelling.

**Keywords:** Flood Modelling; Remote Sensing; GIS; Owerri West; Pairwise comparison

### 1. Introduction

The intensity and amount of rainfall in recent times has resulted in some of the significant flooding within the eastern region of Nigeria, particularly in Imo State in the last few years. with the effects of climate change, heavy and damaging storms will continue to increase in frequency. The exceptionally heavy rainfall of September 2018 in Imo State led to more than 26 deaths and displacement of over 2,500 families. The Seven LGAs in Imo State that were seriously affected were Owerri municipal, Owerri North, Owerri West, Orlu East, Mbaitoli, Isu and Nwangele [1]. The floods were caused by poor drainage systems and the indiscriminate infrastructural development along river banks [1].

The studies of [2], [3], [4] and [5] have modelled flooding in Owerri, Imo State but their results were insufficient and lacked detail, they failed to take into consideration, the poor drainage systems as a leading factor and a major criterion for flood modelling. These studies based their flood modelling only on the use of elevation dataset while ignoring other factors like drainage system, watershed, rainfall, floodplains, mean annual precipitation and mean annual flow, these are critical in tackling the problem of flooding.

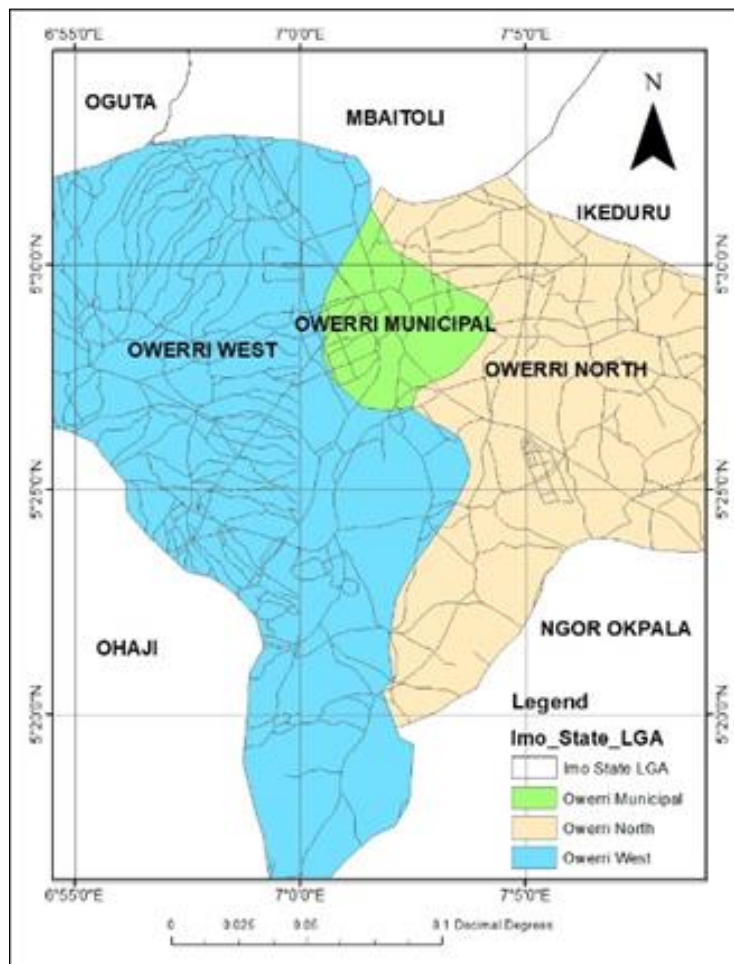
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Therefore, to proffer a better solution to the problem of flooding in Owerri West, Imo State, emphasis must be given to the combination of all interrelated geophysical processes at work. The analysis of all the geophysical flood vulnerability factors can be achieved using an integrated approach of Analytical Hierarchy Process and Flood hazard index. The combination of Analytical Hierarchy Process and Flood hazard index can provide a detailed insight on the flood spatial extent and vulnerability areas in Owerri West, Imo State.

## 2. Material and methods

### 2.1. Study Area

Owerri is the capital of Imo State in Nigeria. It is also the state's largest city, followed by Orlu and Okigwe as second and third respectively. Owerri consists of three Local Government Areas including Owerri Municipal, Owerri North and Owerri West, it has an estimated population of about 1,401,873 as of 2016 and is approximately 100 square kilometers (40 sq mi) in area. Owerri is bordered by the Otamiri River to the east and the Nworie River to the south. It is located between latitude 5.485°N and longitude 7.035°E. See fig 1.



**Figure 1** Map of Owerri (Study Area)

Important educational institutions in Owerri include Imo State University, Federal University of Technology Owerri, Imo State Polytechnic Umuagwo, Federal Polytechnic, Nekede, African Institute of Science and Technology (AIST CCE Owerri), Federal College of Land Resources Oforola, Seat of Wisdom Seminary Owerri, Alvan Ikoku College of Education, Christ the King Secondary School, Obike, Methodist High school, Government Training College, Federal Government Girls College Owerri, Owerri Girls Secondary School, Government Secondary School Owerri, Development Secondary School Owerri, Emmanuel College Owerri, Holy Ghost College Owerri, Obube Comprehensive Secondary School (Egbelu Obube), Obube Secondary School, Community Secondary School Oforola Owerri, Federal Polytechnic Nekede Owerri, Government Technical college Owerri, Army Day Secondary School Obinze Owerri MSME Business School Aladinma Housing Estate, Owerri etc.

The state has several natural resources including crude oil, natural gas, lead, Calcium Carbonate and zinc. Profitable flora including iroko, mahogany, obeche, bamboo, rubber tree and oil palm. Additionally, white clay, fine sand and limestone are found in the state.

## 2.2. Materials

The data used to achieve the aim and objectives of this study are classified into primary and secondary data.

### 2.2.1. The Primary Data

The primary data include: the primary data required from field survey is ground truth data. It was used to assess the accuracy of classified LC maps. For the purpose of accuracy assessment of satellite image, the coordinates of 350 selected ground control points were collected and used to assess the accuracy of classification of images. Random sampling technique were used to determine the location of the points.

### 2.2.2. The Secondary Data

Sentinel-2 of 2018 and ALOS PALSAR imagery covering the study area were used; these was downloaded from the USGS website using the Earth explorer. The digital administrative maps of Nigeria, Imo State were sourced from the QGIS 1.8.0 Lisboa (Tutorial Pack) and Department of Surveying and Geoinformatics, Nnamdi Azikiwe University Awka respectively, Soil data was gotten from [www.ncdc.noaa.gov](http://www.ncdc.noaa.gov)

## 2.3. Methods

Prior to data analysis, initial processing on the raw data were carried out to correct for any distortion due to the characteristics of the imaging system and imaging conditions., although standard correction procedures have been carried out by the ground station operators before the data is delivered to the end-user. These procedures include radiometric correction to correct for uneven sensor response over the whole image and geometric correction to correct for geometric distortion due to Earth's rotation and other imaging conditions (such as oblique viewing). There was no need for further corrections as the image used was in top condition.

This study used the supervised classification in the ArcGIS software. The image classification toolbar in ArcGIS which provides a user-friendly environment for creating training samples and signature files will be used for both supervised.

Alos Palsar DEM was used for this study. It is a topographical model with elevation records of cells in certain size. However, there is still potential of existence off sunken areas because of data error or landform Karst Topography. Data error is mainly caused by the resolution limitation of DEM on both vertical and horizontal direction and system error during the generation of DEM. Due to existence of these sinks, unreasonable flow direction may be generated during the calculation. If these sinks are not filled by technical process, then the generated drainage network will not be continuous.

The process of filling sink is called elevation smoothing or filling depressions. The main purpose of elevation smoothing is to reduce the number of artificial depressions generated by data collection system. The most used procedure of sink fill, taken as the official algorithm in the most wide-used GIS software ArcGIS.

The DEM was processed to fill the sinks present in the elevation dataset; this was done with spatial analyst tool in ArcToolbox. After which slope, elevation and aspect factors were extracted from the dem to be used in the study since water flows from higher to lower elevations and slope influences the amount of surface runoff and infiltration, and also Flat areas in low elevation may flood quicker than areas in higher elevation with a steeper slope.

Areas of concentrated surface water, river overflows are crucial for the initiation of a flood event. Often the inundation emanates from riverbeds and expands in the surroundings. Flow accumulation is the most important parameter in defining flood hazard. Accumulated flow sums the water flowing down slope into cells of the output raster. High values of accumulated flow will indicate areas of concentrated flow and consequently higher flood hazard.

Pairwise comparisons were used to create a ratio matrix. It takes pairwise comparisons as input and produces relative weights as output. The pairwise comparison method involved three steps:

- Development of a pairwise comparison matrix
- Computation of the weights: this involved the summation of the values in each column of the matrix. Then, each element in the matrix was divided by its column total (the resulting matrix is referred to as the normalized pairwise comparison matrix). Then, computation of the average of the elements in each row of the normalized

matrix was done which included dividing the sum of normalized scores for each row by the number of criteria. These averages provided an estimate of the relative weights of the criteria being compared.

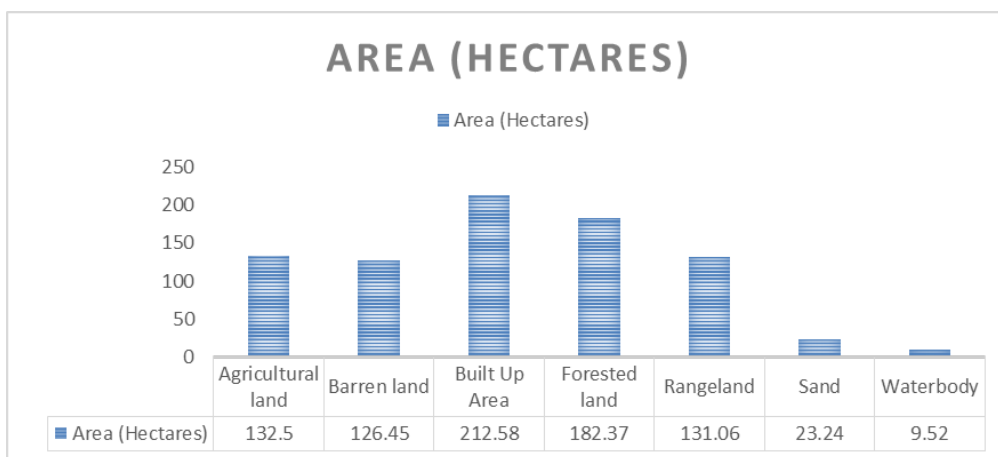
- Ranking the criteria options: This last step involved ranking accomplished by ordering the global score in decreasing order of importance.

After the weights were determined, the individual weighted criteria were combined and overlaid to obtain a flood index scale. The flood index scale was estimated from the values of all the locations on the area under consideration. Thus, the scale was grouped into four main categories of: very high, high, Moderate and low flood vulnerability. Weighted Linear Combination (WLC) was adopted in this study and was executed in the ArcGIS environment.

### 3. Results and discussion

#### 3.1. Vulnerable areas in Owerri West

Breaking down the vulnerable areas in Owerri West, in high flood vulnerability zone, agricultural land occupied 16.20% with an area coverage of 132.50 hectares, barren land occupied 15.46% with an area coverage of 124.45 hectares, built up area occupied 26% with an area coverage of 212.58 hectares, forested land occupied 22.30% with an area coverage of 182.37 hectares, rangeland occupied 16.03% with an area coverage of 131.06 hectares, sand occupied 2.84% with an area coverage of 23.24 hectares and waterbody occupied 1.16% with an area coverage of 9.52 hectares, see figure 2.

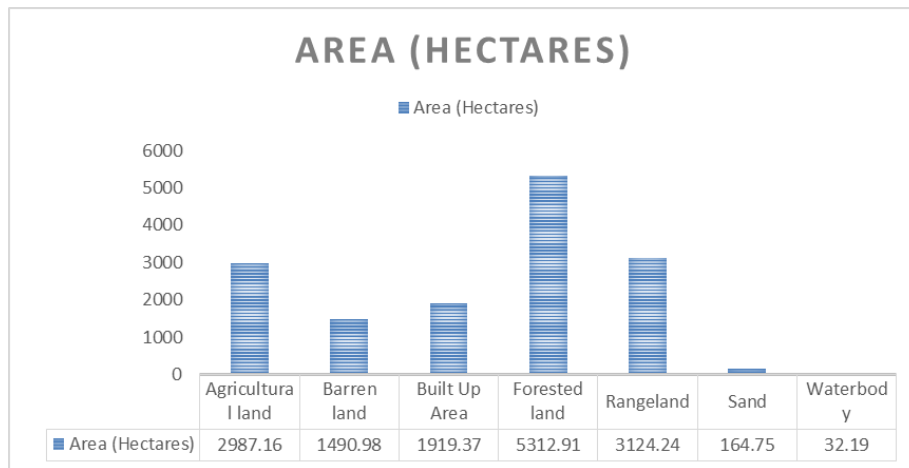


**Figure 2** Highly vulnerable areas in Owerri West

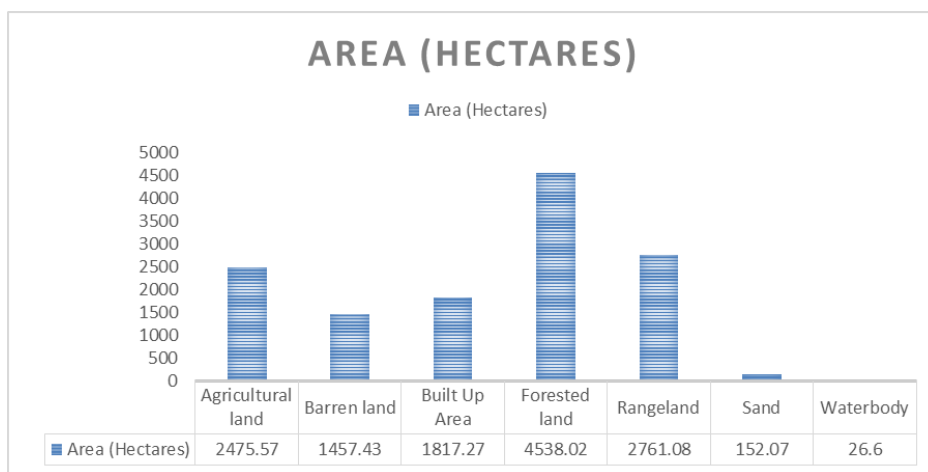
In moderate flood vulnerability zone, agricultural land occupied 19.87% with an area coverage of 2987.16 hectares, barren land occupied 9.92% with an area coverage of 1490.98 hectares, built up area occupied 12.77% with an area coverage of 1919.37 hectares, forested land occupied 35.34% with an area coverage of 5312.91 hectares, rangeland occupied 20.78% with an area coverage of 3124.24 hectares, sand occupied 1.10% with an area coverage of 164.75 hectares and waterbody occupied 0.21% with an area coverage of 32.19 hectares, see figure 3.

In low flood vulnerability zone, agricultural land occupied 18.71% with an area coverage of 2475.57 hectares, barren land occupied 11.02% with an area coverage of 1457.43 hectares, built up area occupied 13.74% with an area coverage of 1817.27 hectares, forested land occupied 34.31% with an area coverage of 4538.02 hectares, rangeland occupied 20.87% with an area coverage of 2761.08 hectares, sand occupied 1.15% with an area coverage of 152.07 hectares and waterbody occupied 0.20% with an area coverage of 26.60 hectares, see figure 4.

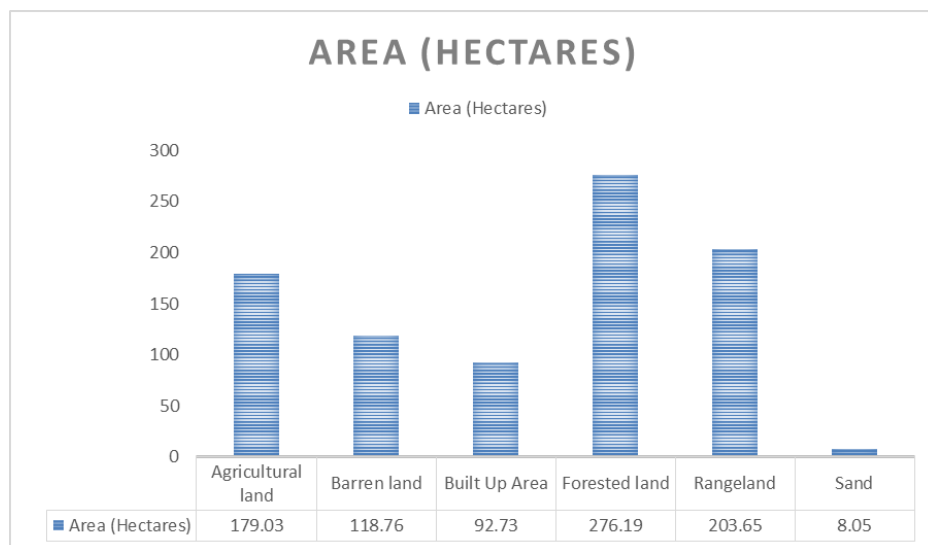
In no flood vulnerability zone, agricultural land occupied 20.30% with an area coverage of 179.03 hectares, barren land occupied 13.46% with an area coverage of 118.76 hectares, built up area occupied 10.51% with an area coverage of 92.73 hectares, forested land occupied 31.31% with an area coverage of 276.19 hectares, rangeland occupied 23.09% with an area coverage of 203.65 hectares, sand occupied 0.91% with an area coverage of 8.05 hectares and water body occupied 0.41% with an area coverage of 3.65 hectares, see figure 5.



**Figure 3** Moderately vulnerable areas in Owerri West



**Figure 4** Low vulnerable areas in Owerri West



**Figure 5** No vulnerable areas in Owerri West

#### **4. Conclusion**

This study developed an approach using an open GIS model workflow in ArcGIS model builder which was used to model flood vulnerability in Owerri West while incorporating eight criteria deemed to be responsible for flood vulnerability. The generated model can be exported to python script for easy implementation and update, making it easier for researchers and planners to adopt, change and add more factor or directly use the model as it is in flood vulnerability analysis in any part of the country. The study was also able to produce flood vulnerability maps covering Owerri West this is an addition to spatial data availability for the study area. This can be used as a tool for planning and decision making in flood disaster management studies.

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#### **Compliance with ethical standards**

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##### *Disclosure of conflict of interest*

There is no conflict of interest regarding the research, authorship and publication of this paper.

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