FLOOD VULNERABILITY MAPPING OF OGBARU LOCAL GOVERNMENT AREA, ANAMBRA STATE, NIGERIA.

Keywords: Flooding, vulnerability, multi-criteria analysis, Analytic Hierarchy Process, Remote Sensing, Geographic Information System (GIS), Ogbaru Local Government Area (LGA).

SUMMARY

Globally, flooding has become inevitable occurrence increasing rapidly in different parts of the world, including Nigeria. It is a common natural disaster in Nigeria that destroys quantum of lives and infrastructures. This study is basically on flood vulnerability mapping of Ogbaru Local Government area (LGA), Anambra State, Nigeria, to determine highly vulnerable, moderately vulnerable, vulnerable and less vulnerable area to flood. (Shuttle Radar Topographic Mission) (Digital Elevation Model) SRTM DEM 30m was used to generate the flood contributory parameters; Slope, Distance to River, Flow Direction, Flow Accumulation, Basin, Watershed, Drainage Density. Sentinel 2 image of 10m resolution was used to derive Land Use/Land Cover of the area using maximum likelihood algorithm in supervised classification. Other parameters such as soil and rainfall were also derived. Multi Criteria Analysis (MCA) method using Analytic Hierarchy Process (AHP) was employed where ten criteria including: Slope, Flow Direction, Flow Accumulation, Basin, Watershed, Drainage Density, Distance to River, Land use/cover, Rainfall and Soil were assigned weights according to their order of importance from the most to least desirable criteria. Subsequently the criteria were reclassified into five classes with the reclassify algorithm using ArcMap 10.8.2 software, weighted overlay model was used to generate flood susceptibility map of Ogbaru Local Government Area. The Multi Criteria Analysis revealed that the Mean Annual Rainfall (MAR) which was 28% contributed more to flooding than other factors considered in the model followed by distance to river (20%), slope (15%), soil (9%) and basin (6%). The percentage of areas vulnerable to flood shows Highly Vulnerable (2%), Vulnerable (39%), Moderately Vulnerable (55%), Less Vulnerable (4%). Accuracy assessment of the supervised image classification was performed using the confusion matrix algorithm. The flood inventory maps of 2018, 2020 and 2022 from Nigeria Hydrological Services Agency (NIHSA) was used to validate the accuracy of the flood vulnerability map. High accuracy of the AHP model and weighted overlay model serves as a viable approach in the prediction and mitigation of flood. This study called for strategic prediction, monitoring, mitigation and prevention of flood.

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1. INTRODUCTION

Universally natural hazard is increasing at an alarming rate, as results of climate change. These natural hazards include: tsunami, hurricane, earthquake, landslides, forest fire, and flood. Flood is the most common, deadliest and costliest natural disasters in Nigeria. Flood is the utmost frequent type of natural disaster. It occurs when an overflow of water submerges land that is usually dry. A river flood occurs when water levels rise over the top of river banks. This flooding can happen in all river and stream channels. There are several human causes of flooding, including poorly designed infrastructure, blockage of drainage using refuse, deforestation. There are also natural reasons flooding happens. The most common causes of flooding, includes: heavy precipitation, overflowing river, broken dams, storm surges and tsunamis, lack of vegetation, melting snow and ice (B-AIR,2020).

The impact of flood worldwide cannot be overemphasized. According to the United Nations Educational, Scientific and Cultural Organization (UNESCO), World Water Assessment Program (WWAP), (2022), which provided a clear statement on the problem of flooding, of all water-based natural hazards (landslide & avalanche 9%, famine 2%, water-related epidemic 11%, drought 11%, and flood 50%), flooding makes up a significant figure of 50% and accounts for 15% of all deaths related to natural disaster World Meteorological Organization (WMO,2011).

The most immediate flood consequence is the destruction of homes. People get displaced and may have to evacuate to higher ground where their lives are at risk as long as the waters remain on a certain level. The destruction of structures such as bridges and roads prevent help from reaching devastated areas. Damages caused by flood are immediate. Lives are lost, properties are wrecked, crops are destroyed. Flooding causes severe damage, disrupts economic processes and causes food shortage. Consequences of flooding on property value cause areas prone to flooding to experience decrease in real estate value. Flooding impact, especially in urban areas, is enormous. The flood destruction in cities disrupts business, commerce, and tourism.

Nigeria is located downstream of River Niger and Benue, and therefore abounds with water resources that cause flood menace. The worst of the menace was experienced in 2012 when hundreds of lives were lost, thousands of citizens rendered homeless, heavy property loss and massive destruction of farm lands and crops. Apart from local rainfall, transboundary flows from River Niger and Benue have continued to aggravate flooding in the country. The devastating impact of 2020 flooding affected 36 states including Federal Capital territory (FCT), 349 Local Government Area and 2,353,647 people. 69 fatalities were recorded Nigeria Hydrological Services Agency (NIHSA,2021).

This study looked at the use of Remote Sensing and Geographic Information System (GIS) technique in producing flood vulnerability map of Ogbaru LGA, Anambra. The Sentinel 2 imagery used for Landuse/landcover analysis and the Digital Elevation Model used for the generating the flood contributory factors were obtained through the Remote Sensing technique, while weighted overlay analysis was carried out in the GIS environment to determine the flood vulnerability map of Ogbaru LGA. Multi-criteria Decision Analysis (MCDA) was also adopted where Analytical Hierarchy Process was used to rank the flood contributory factors in order of their importance. Analytical Hierarchy Process was also used to assign weights to each parameter. In order to identify a degree of the susceptibility, flood vulnerability map can be constructed using the flood conditioning parameters in the environment of GIS. GIS is effective tool to determine the high risk of flood prone areas down to small hydrological basins. The efficiency of MCDA) and GIS was assessed by Fernandez & Lutz (2010) for mapping the flood-susceptible areas in Tucuman Province, Argentina. The study showed that the AHP method in GIS environment is a powerful technique to generate disaster hazard maps with a reasonable accuracy. Zou *et al. (*2013) recognized AHP technique as an understandable, convenient and cost-effective method for flood hazard evaluation. Subramanian & Ramanatha (2012) indicated that the AHP technique is suitable for regional researches.

According to Hwang & Yoon (1981) Multi-criteria decision analysis (MCDA) has been identified as an essential tool for analyzing complicated decision problems, that include incomparable data or criteria. According to Malczewski (2006), Analytical Hierarchy Process (AHP) is a popular method of multi-criteria decision-making. The Analytical Hierarchy Process (AHP) is one of MCDA techniques which is a qualitative technique in which the process and its application rely on the expert's knowledge in assigning weights Saaty (1980).

GIS and Remote Sensing (RS) techniques provide an application for natural disaster risks analysis, Haq *et al* (2012); Jaafari *et al.*, (2014). Therefore, these techniques have been proposed to evaluate flood hazard zoning in many studies Dewan *et al*, (2007); Pradhan *et al*, (2011); Kazakis *et al.*, (2015)

Flood vulnerability mapping and assessment is an important element of flood prevention and mitigation strategies because it identifies the most vulnerable areas based on physical characteristics that determine the propensity for flooding. Thus, the delineation of the flood prone areas is a strategic input in any flood mitigation strategy.

Furthermore, the flood vulnerability map can form a basis for decision and policy-makers to make a data driven decision and subsequently, reduce the damage and economic losses caused by flood disasters. The results of this timely study will offer reference for country-wide disaster impact and risk assessments, especially for national and local governments to make informed emergency preparedness, response, mitigation, and recovery policies and plans.

Consequently, the main objective of this study is exclusively based on producing a flood vulnerability map of Ogbaru LGA by using the integration of MCDA (AHP), weighted overlay model and GIS techniques.

2. MATERIALS AND METHODS

2.1 Location of the Study Area

Ogbaru Local Government Area is one of the twenty-one Local Government Areas in Anambra state, South-east geopolitical zone of Nigeria with its headquarters in Atani. It is located between latitude 6°40"00' N, longitude 6°38"00' E and latitude 5° 47"30'N, longitude 6°49"00' E covering an area of 453,516 sqm. It is bounded by ten Local Government Areas which include Oshimili South and Ndokwa in Delta State, Onitsha North, Onitsha South, Idemili North, Idemili South, Ekwusigo, Ihiala, in Anambra State, Oguta in Imo State, and Ogba/Egbema/Ndoni in Rivers State. (See Fig 1). It is also bounded by river Niger to the west. River Niger, Idemili River and River Ulasi constitutes the major river in the area, with other tributaries. The study area is close to the bank of River Niger. The depth of River Niger is shallow because of lack of dredging, which cause water to overflow its bank especially during rainy season causing flooding in the area.

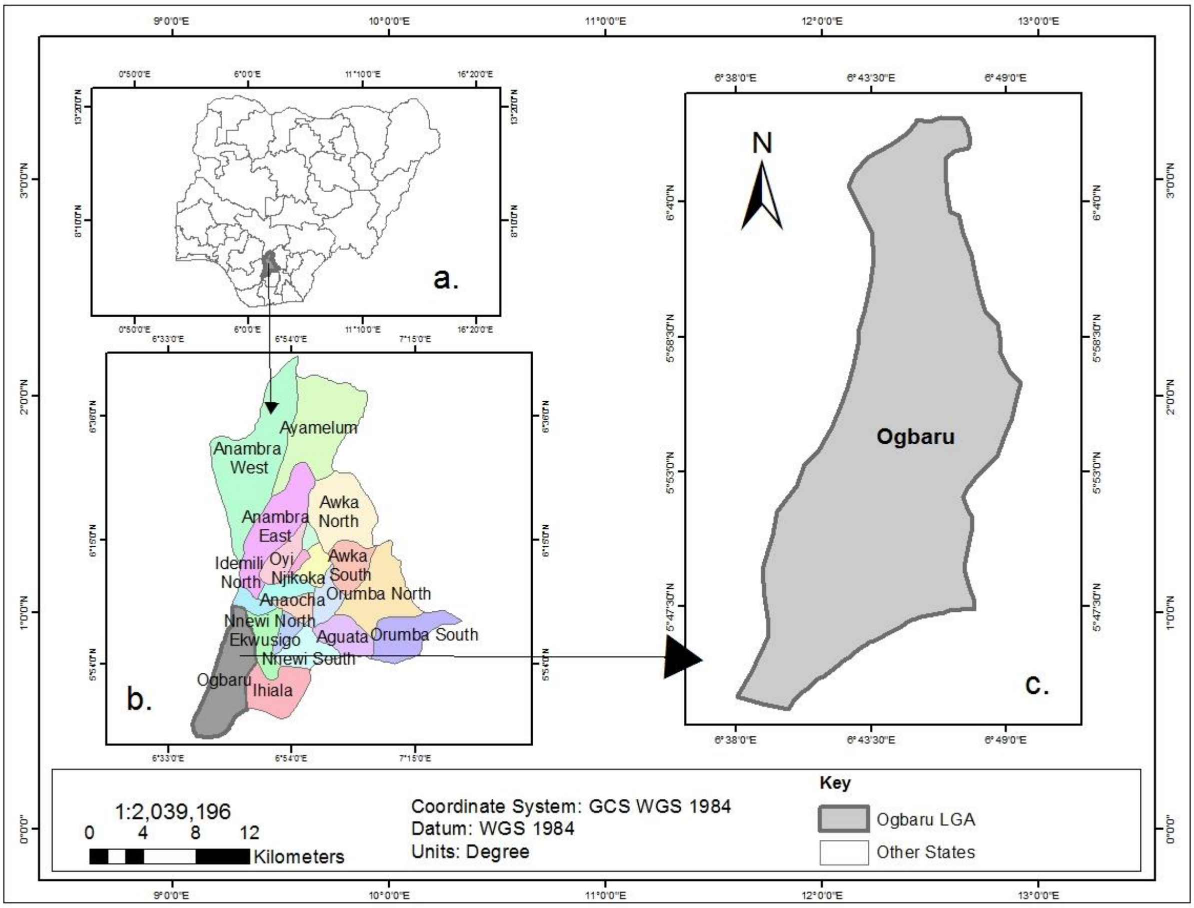

Figure 1: Location of Ogbaru LGA, Anambra State, Nigeria.
Source: Office of the Surveyor General of the Federation (OSGoF)

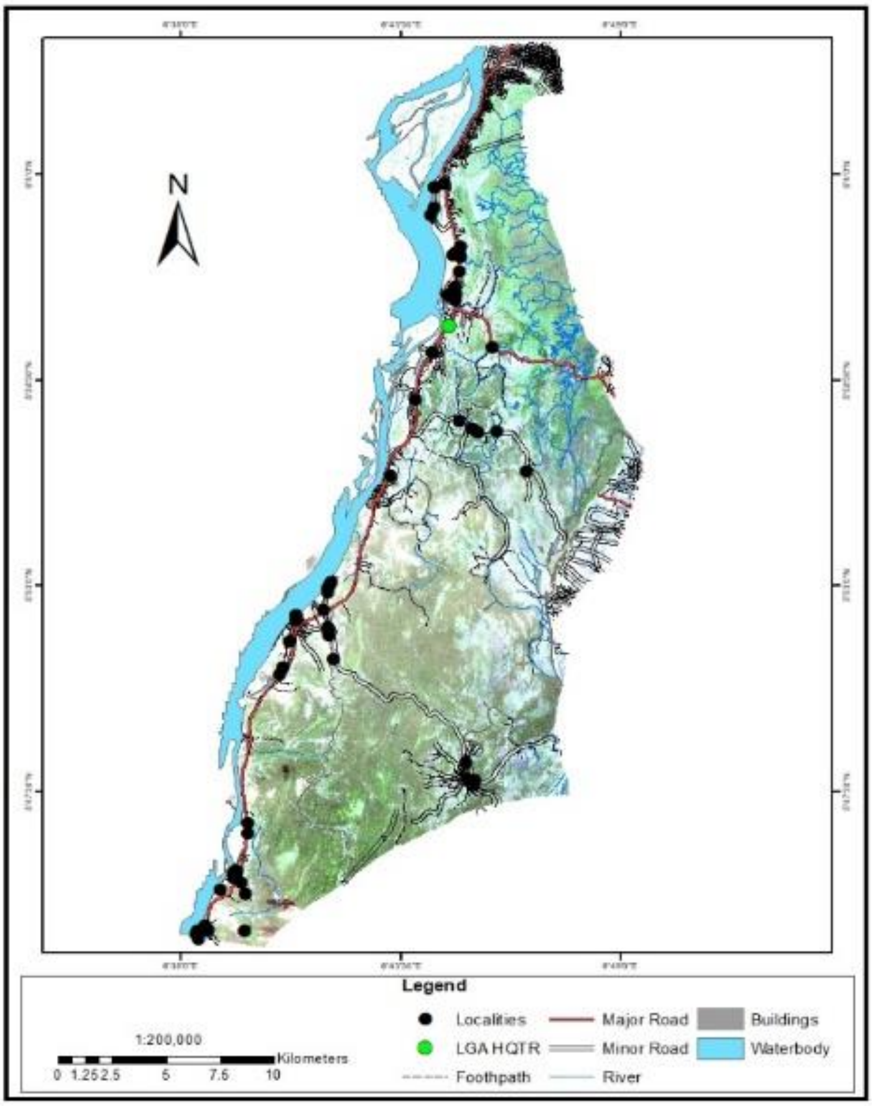

Figure 2: Image Map of Ogbaru LGA. Source: (OSGoF)

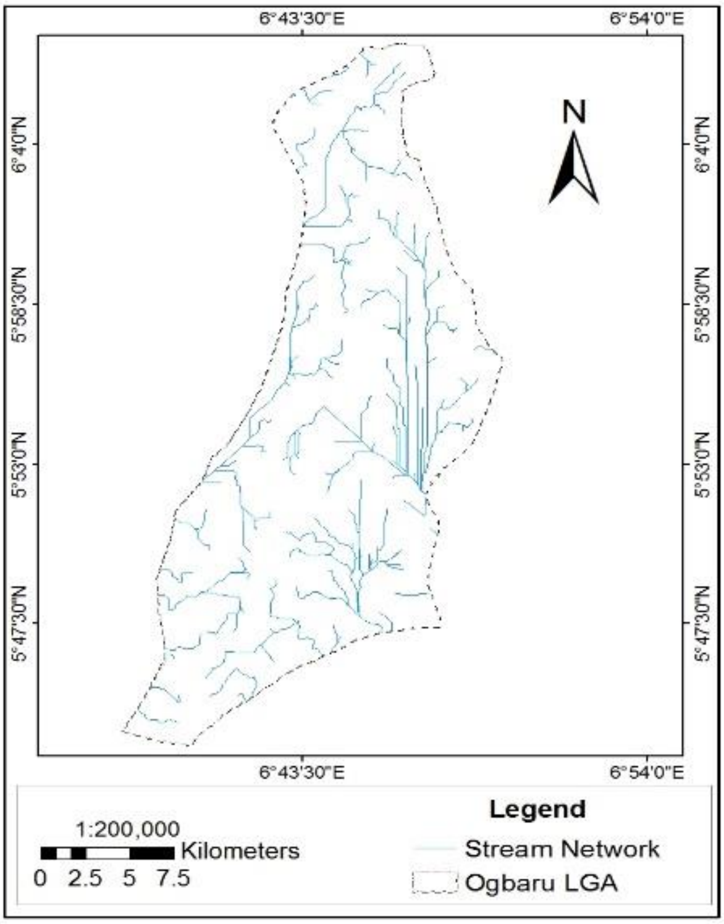

Figure 3: Stream Network of Ogbaru LGA
Source:(DEM) from USGS Earth Explorer, computed by the Author.

2.2 Materials

Materials used in this study include;

i. Satellite Imagery (Sentinel 2 of 10m resolution) covering Ogbaru Local Government Area, for image interpretation and supervised image classification;
ii. Administrative Map of Nigeria (digital format) for boundary definition of the study area;
iii. Shuttle Radar Topographic Mission (SRTM) Digital Elevation Model (DEM) of 30m resolution, for generating Slope, Flow Direction, Flow Accumulation, Stream Order, Drainage Density, Distance to River, Basin, Watershed;
iv. Annual Rainfall Data for generating rainfall map;
v. Soil data for generating soil map;
vi. ArcGIS 10.8.2 was used for data analysis, accuracy assessment, creating thematic maps and map embellishment.
vii. ERDAS Imagine 2015 was used for image subset of Ogbaru LGA and supervised image classification;

viii. Google Earth was used for accuracy assessment of image classification.

Table 1: Datasets and sources.

Name	Sheet	Date	Format	Source	Scale	Coordinate System	Purpose
Administrative Map of Nigeria	187	1979	Digital	OSGOF	1:50,000	WGS 1984	For boundary definition of the study area.
Satellite Imagery	Sentinel II	2021	Digital	Copernicus open access hub https://scihub.copernicus.eu/dhus/#/home	10m	WGS 1984	For image classification
STRM DEM	n05_e006_1arc_v3.tif n06_e006_1arc_v3.tif	2021	Digital	United State Geological Survey USGS http://www.earthexplorer.usgs.gov/	30m	WGS 1984	For generating Slope, Flow Direction, Flow Accumulation, Stream Order, Drainage Density, Distance to River, Basin, Watershed
Annual Rainfall Data		2020	Digital (.tiff format)	CHRS DATA PORTAL PERSSIAN-Cloud Classification System (PERSSISN-CCS)		WGS 1984	Rainfall Map

				https://chrsdata.eng.uci.edu/			
Annual Rainfall Data		2012 – 2020	Microsoft Excel	NASA Prediction of Worldwide Energy Resources (POWER) https://power.larc.nasa.gov/		WGS 1984	Rainfall Chart Hydrograph
Soil Data		2003	Digital	Food and Agricultural Organization (FAO). European Soil Data Center (ESDAC)	1:5,000,000	WGS 1984	Soil Map

2.3 Instruments

Handheld Global Positioning System (GPS) Garmin 60CSx was used for direct collection of information of features on the field like rivers, waterbodies, towns, etc. The location of the rivers and waterbodies was picked with GPS. The rivers and waterbodies were later extracted through on-screen vectorization using ArcGIS Software. The GPS was set in waypoint mode to determine the spatial and attributes features. The points (coordinates) which were the Longitude and Latitudes which described the positions of the features acquired during the groundtruthing were later transferred into the system via map source application and then imported into Microsoft Excel Worksheet and was saved in .xls file extension before added as a layer on the map for proper editing and feature identification. Therefore, the exercise was carried out for the purpose of verifying the true ground situation in relation to what is on the imagery.

2.4 Methods

This section described the approaches which were employed in the study towards fulfilling the objectives of the study. It presents the flow diagram that summarised the activities of the study. It also gives a comprehensive framework and methods that was adopted in data acquisition, data creation, data processing and manipulation involved in the production of a flood vulnerability map of Ogbaru LGA. Fig 4 shows the methodology work flow that summarised the methods employed in the study.

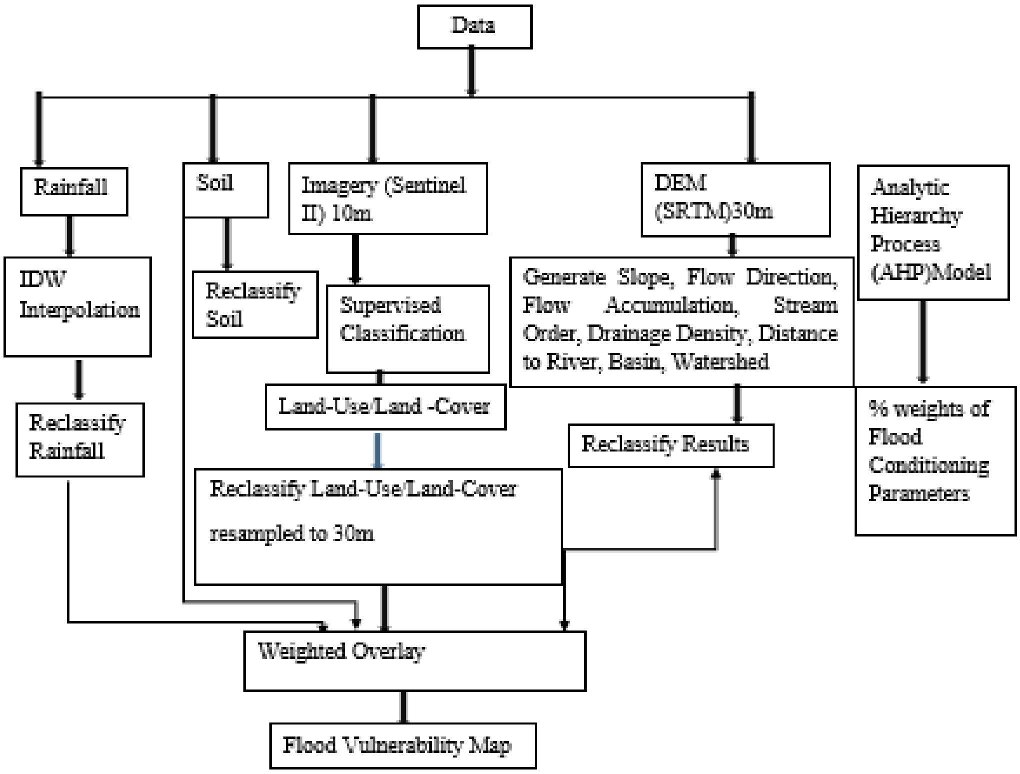

Figure 4: Methodology work flow of the study.

2.4.1 Data Processing

The Shuttle Radar Topographic Mission (SRTM) satellite data of 30m resolution acquired from United State Geological Survey (USGS) of the study area was processed within a GIS software environment, using ArcGIS 10.8.2 software. The Hydrology toolset which is an algorithm under the spatial analyst tool in Arc toolbox was used to generate the hydrological attributes such as flow direction, flow accumulation, stream network, drainage density, the drainage distance, basin and watershed of the study area. Terrain feature such as slope was generated using surface toolset, which is also a sub-tool under spatial analyst tool. The annual rainfall data was converted to points and then interpolated using the Inverse Weighted Distance (IDW) interpolation method. The soil data which is in a shapefile format was converted in to raster, using the polygon to raster conversion tool. The drainage density was calculated from the Stream network vector dataset using the line density tool, which is an algorithm of the density tool in the spatial analyst tool. The distance to river was calculated from the stream network vector dataset using the Euclidean distance tool which is an algorithm of distance tool in the spatial analyst tool. DEM was derived from Shuttle Radar Topographic Mission (SRTM) data.

Sentinel 2 (10m) resolution image was resampled to 30m, for the purpose of carrying out weighted overlay analysis, in other to harmonize its spatial resolution with the Digital Elevation Model (DEM). Supervised classification using the maximum likelihood algorithm was performed to generate the Land Use/ Land Cover of the study area. After the classification, an accuracy assessment was carried out by generating 100 accuracy assessment points in ArcMap environment. The accuracy assessment points were exported as a kml file to be displayed in google earth. The classified points were compared to the points in google earth, after which the confusion matrix was computed to generate the accuracy assessment report and the Kappa statistics of 0.715.

2.4.2 Digital Elevation Model

The boundary extent of the Digital Elevation Model of Ogbaru LGA was extracted from the administrative map of Anambra State; (Ogbaru LGA) boundary, using the extract by mask tool in the extraction tool set, in spatial analyst tool in ArcGIS software. The geometry of the administrative boundary was used to define the extent of the output raster. The elevation map used in this study was generated from SRTM-DEM of 30m resolution (See figure 5). A fill operation was performed on the DEM using the fill tool in the hydrology tool set in the spatial analyst tool of the ArcMap. It was categorized into two classes showing the lowest to the highest elevation points. The lowest elevation point is 14m, while the highest elevation point is 80m respectively.

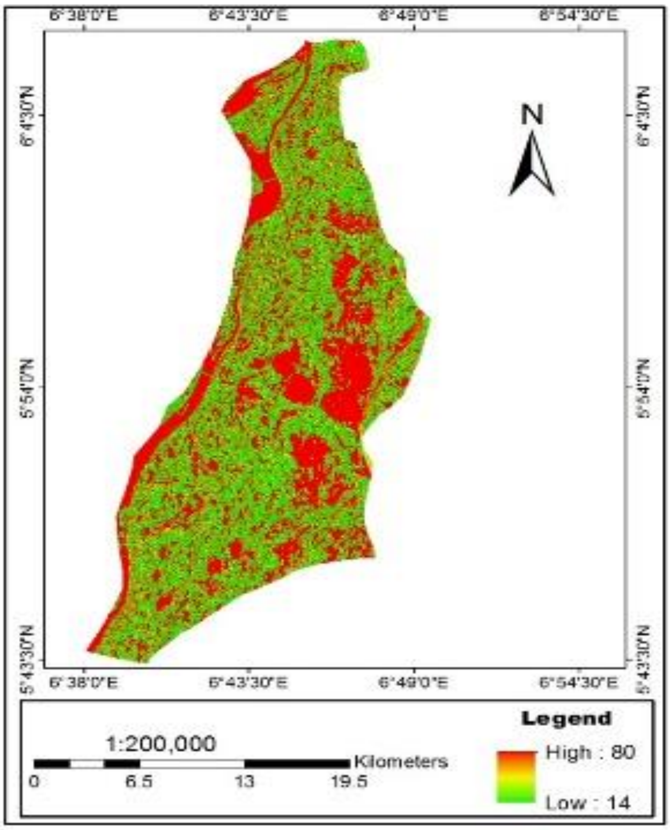

Figure 5: STRM DEM of Ogbaru LGA. Source: USGS Earth Explorer

2.4.3 Land Use/Land Cover Classification

Supervised classification using the maximum likelihood algorithm in ERDAS Imagine environment was used to generate four main land use land cover classes based on Anderson classification scheme (1976) from Sentinel 2 (10m) resolution imagery Figure 6: shows; (1) Bare land, (2) Built up area, (3) Vegetation, (4) Water body. The vegetation accounted for 67% of total area, bare land accounted for 14%, water body accounted for 6%, and built-up area accounted for 12%, signifying agriculture was an important economic activity, as shown in the Land Use/ Land Cover map of the study area.

Table 2: The Land Use/Land Cover Distribution of Ogbaru LGA. Source (Author's classification Result)

S/N	Land Cover Types	Area Covered (km^2)	Percentage (%)
1.	Vegetation	306	67
2.	Water Body	28	6
3.	Built up area	57	12
4.	Bare Land	63	14

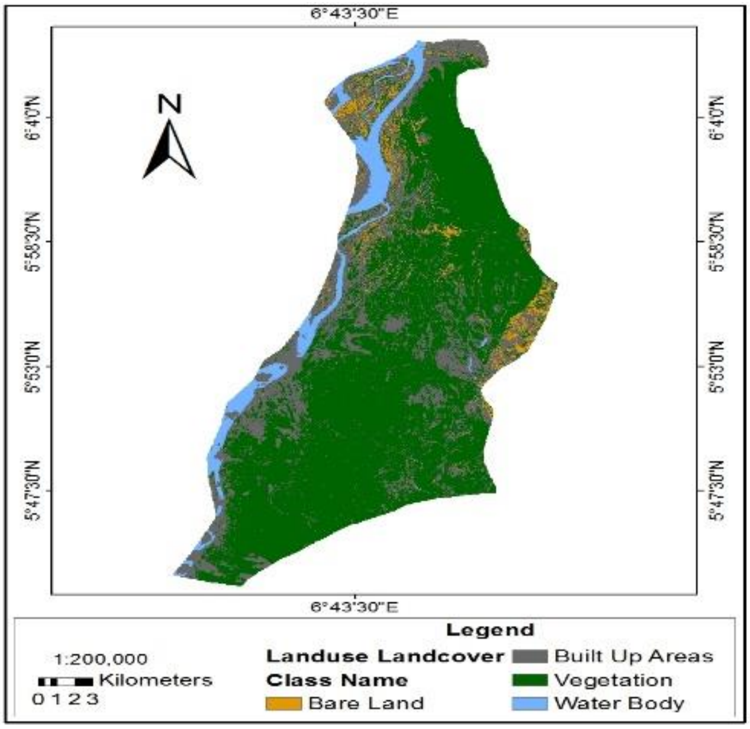

Figure 6: The Land Use/Land Cover map of Ogbaru LGA, Anambra State, Nigeria

Table 3: Accuracy Assessment using Confusion Matrix. Source (Author's computation)

OBJECT ID	Class Value	Vegetation	Waterbody	Built-up	Bare land	Total	User Accuracy	Kappa
1	**Vegetation**	63	0	0	2	65	0.969230769	0
2	**Waterbody**	0	6	0	0	6	1	0
3	**Built-up**	3	1	5	8	17	0.294117647	0
4	**Bare land**	1	0	0	11	12	0.916666667	0
5	Total	67	7	5	21	100	0	0
6	**Producer Accuracy**	0.940298507	0.857142857	1	0.523809524	0	0.85	0
7	Kappa	0	0	0	0	0	0	0.715

Table 3, shows confusion matrix which displays the accuracy of the supervised image classification carried out. This matrix explains information about the actual and predicted identification of pixels. Accuracy is the percentage of correctly classified instances out of all instances. The confusion matrix algorithm was used where 100 samples of accuracy assessment points were generated and compared with the grid codes or pixel numbers of the classified image using google earth image as a reference image. It also shows the Overall accuracy, the producer accuracy, the user accuracy and the Kappa's Coefficient. Over all Classification accuracy, measures the number of correct predictions made divided by the total number of predictions made. Producer accuracy is calculated by dividing the number of correctly classified pixels in each category by either the total number of pixels in the corresponding column. User accuracy represents the probability that a pixel classified into a given category actually represents that category on the ground. The Producer accuracies for Vegetation, Waterbody, Built-up and Bare land are as follows; 0.940, 0.857, 1 and 0.523. The Overall accuracy of the supervised image classification in this study is 0.85. The user accuracy for Vegetation, Waterbody, Built-up and Bare land are as follows; 0.969, 1, 0.294 and 0.917. The Kappa's Coefficient or Kappa's statistics in this study is 0.715, which is very acceptable and is 1 when approximated. The K(Kappa) value ranges between 0 and 1, where 0 represents poor agreement and 1 represents almost perfect agreement between the actual and predicted pixels. Bogoliubova & Tymków, (2014). Kappa statistics is considered the most experienced measures of accuracy of LULC maps as it provides much better interclass discrimination.

2.5 Multi Decision Criteria Approach (MDCA)

The MCDA allows geospatial datasets to be weighted to reflect their relative influences. This study adopted the Analytic Hierarchy Process (AHP) model over a range of MCDA methods to determine the conditioning factors' weights. The AHP method involves the following steps:
(a) to itemize a decision-making problem into component factors;

(b) to prepare the components in hierarchical order;

(c) to assign numerical values based on their relevance;

(d) to build a comparison matrix;

(e) to compute the normalized eigenvector which determines the weights of each component (Saaty & Vargas, 2012).

According to (Kishore Chandra Swain et al.,2020), AHP is a multi-perspective multi-objective decision-making model that enables users and planners to quantitatively derive a scale of preference drawn from a set of alternatives. The Analytic Hierarchy Process, also analytical hierarchy process, is a structured technique for organizing and analyzing complex decisions, based on mathematics and psychology. It represents an accurate approach to quantifying the weights of decision criteria. (Zou *et al.*, 2013) recognized AHP technique as an understandable, convenient and cost-effective method for flood hazard evaluation. (Subramanian & Ramanathan, 2012) indicated that the AHP technique is suitable for regional researches. Michael Msabi & Michael Makonyo (2020), applied the use of GIS and Multi-Criteria Decision analysis for flood susceptibility mapping of Dodoma region in central Tanzania. They used the Analytical Hierarchy Process methodology which is an interactive decision-making approach under multi-criteria decision analysis. Kamonchat Seejata *et al.,* (2017), aimed at assessment of flood hazard areas using Analytical Hierarchy Process over the Lower Yom Basin, Sukhothai Province. In their study, the results of produced flood area using AHP revealed the same districts as in comparison with the extent of flood observed by GISTDA using active sensor satellite imageries during years of 2010-2014 to calculate flood frequency maps and reclassify the frequencies as same as classes used in AHP map. AHP Multi Criteria Decision analysis was used in this study to assign weights of importance to the flood contributory parameters used and it proved to be an effective tool in deriving a flood vulnerability map. In this study the Ten (10) flood conditioning factors were categorized and ranked according to their order of importance. The parameters were compared with each other and ranked in order of importance. In this study a total number of 45 comparisons was done and the Consistency Ratio (CR) was 0.3. The 0.3 consistency ratio showed that the departure was not much, compared to the standard ratio of 0.1 by Saaty. The consistency ratio of each size of matrix measures the degree of departure from the pure inconsistency. (Saaty 1980), defined it as the ratio of a consistency index to the mean consistency index from a large sample of randomly generated matrices.

2.7 Reclassification

According to U.E Akpovwovwo (The Nigerian Journal of cartography and GIS, Vol.8 No.1, p. 60,2013). Reclassification involves the distribution of the data into different classes based on a number of criteria. The reclassify tool was used to reclassify the values in the raster. It was used to reclassify the raster to produce areas of a particular elevation range in order to actualize low plains, moderate and the high plains within the study area. According to the intensity of importance, the ten contributing factors to flood which include Slope, Flow direction, Flow Accumulation, Stream network, basin, Watershed, drainage Density, Distance to River, Land use/cover, rainfall and soil were all reclassified into five classes. If point values are divided into five classes, points in the highest class will fall into the top five of all points (ESRI, 2014). The reclassified map as shown below based on the intensity of importance from the AHP model were used as input data to compute the flood susceptibility map of Ogbaru LGA.

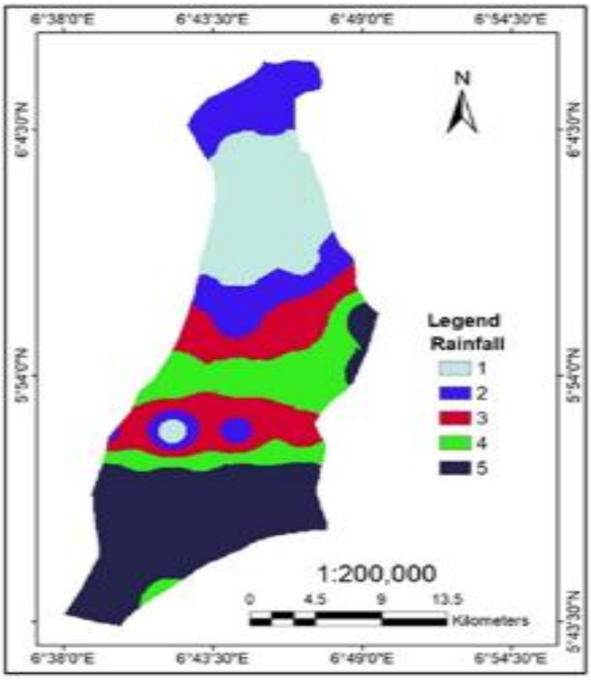

Figure 7: Reclassified Rainfall. Source (DEM)

Figure 8: Reclassified Stream Order. Source (DEM)

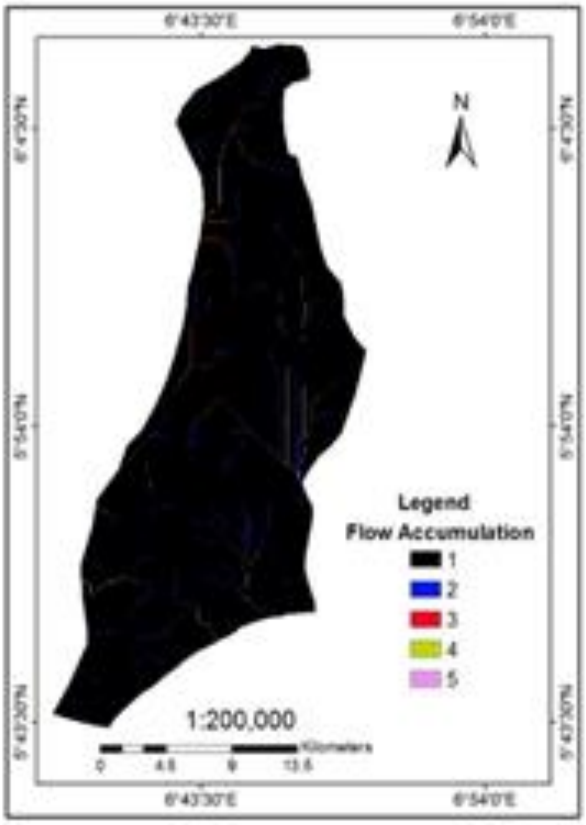

Figure 9: Reclassified Flow Accumulation. Source (DEM)

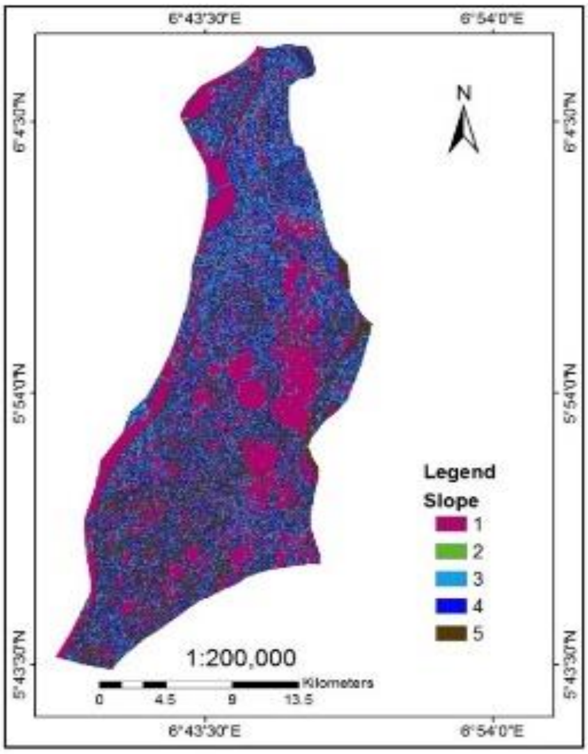

Figure10: Reclassified Slope. Source (DEM)

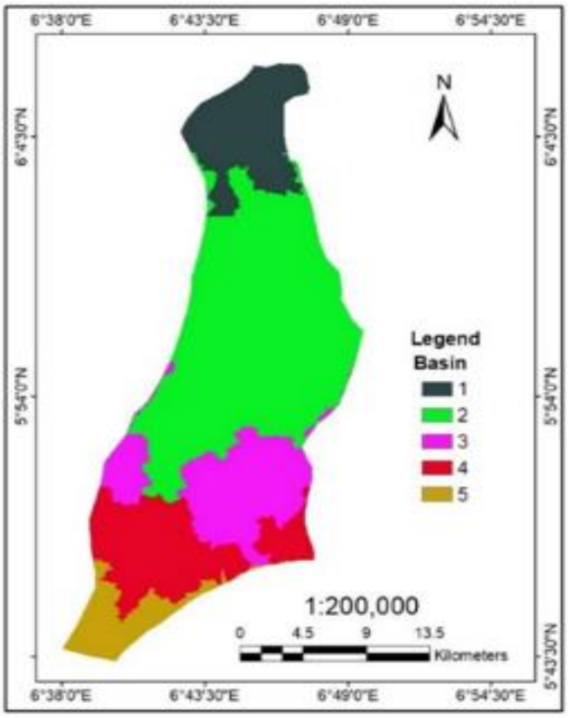

Figure11: Reclassified Basin. Source (DEM)

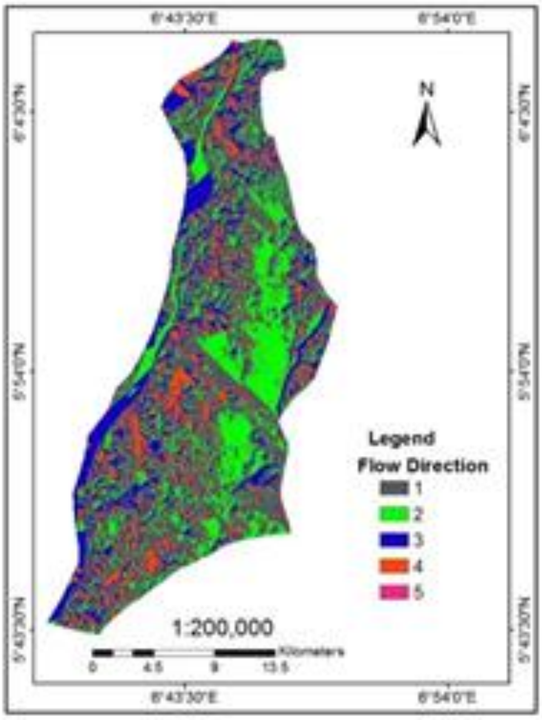

Figure12: Reclassified Flow Direction. Source (DEM)

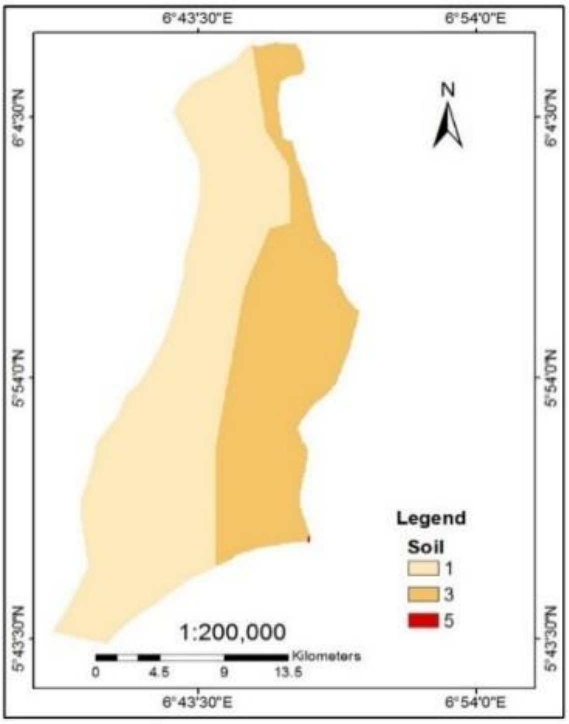

Figure13: Reclassified Soil . Source (DEM)

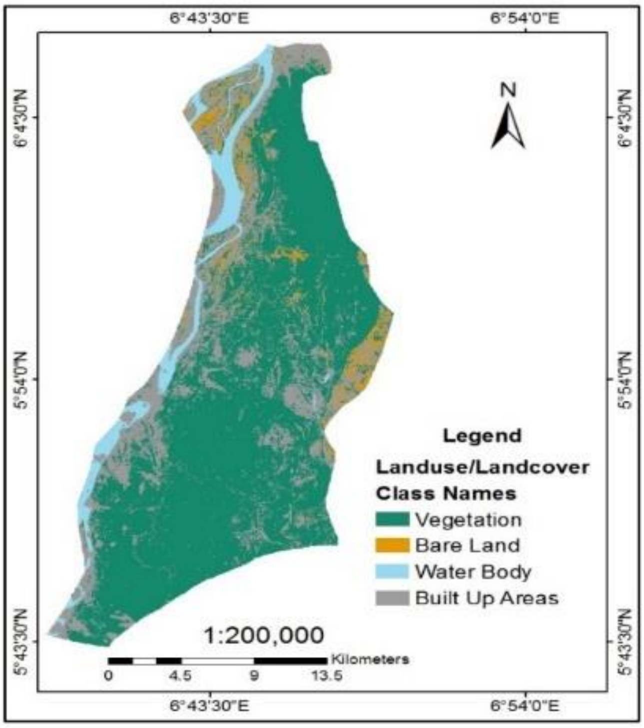

Figure14: Reclassified LULC. Source (DEM)

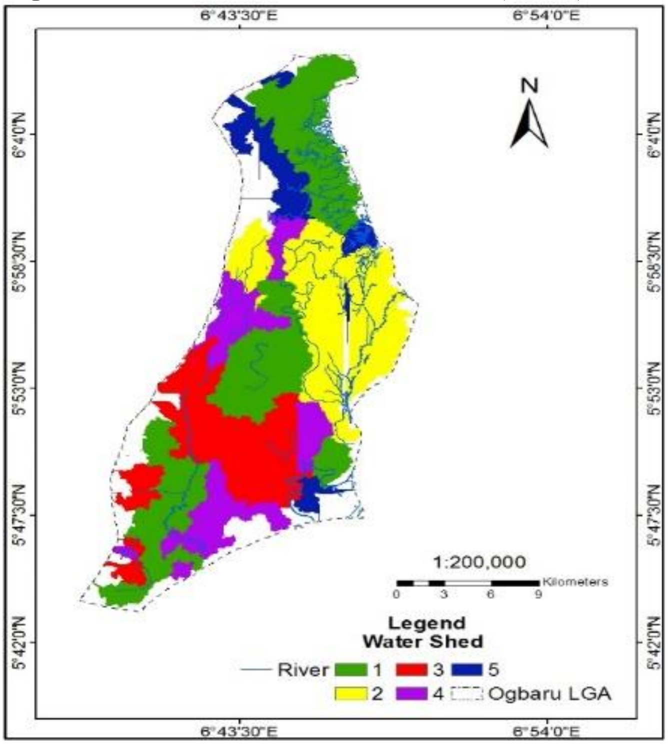

Figure 15: Reclassified Watershed. Source (DEM)

2.8 Weighted Overlay

The weighted overlay algorithm in spatial analyst tool of the ArcMap was used to generate the flood susceptibility map of Ogbaru LGA. The reclassified rasters were added, and the percentage weights were attached to each raster. The percentage weights equals 100. The weights were as follows;

The weighted overlay analysis was carried out at scale 1:5. The result of the operation showed an overlay of the reclassified rasters as single image. The pixel size of all the rasters were 30m, the coordinate system of the rasters were in World Geographic System (WGS) 84. The result was classified into four classes showing highly probable, moderately probable, probable and less probable areas vulnerable to flood.

Table 4: Analytical Hierarchy Process (AHP) % weights of parameters.

S/No.	**Flood Conditioning Parameters**	**Priority (%)**	**Rank**
1	Rainfall	28	1
2	Distance to River	20	2
3	Slope	15	3
4	Basin	6	4
5	Flow Accumulation	5	7
6	Flow Direction	2	10
7	Drainage Density	8	5
8	Watershed	3	9
9	Land use/Land cover	3	8
10	Soil	9	4

The AHP priority calculator software was used to carry out the pairwise comparism of the ten criteria, after which weights were assigned to them by the software according to their order of importance and the magnitude of which they contribute to flood.

3. RESULTS AND DISCUSSIONS

3.1 Flood Vulnerability Mapping

Ten contributing factors were examined. These include rainfall, distance to river, slope, basin, flow accumulation, flow direction, drainage density, watershed, land use/land cover and soil. The impact of each of the above contributing factors was examined by introducing them one after the other in the model. The result shows a very close representation of the reality. The contributing percentage for the factors are Mean Annual Rainfall (MAR) (28%), distance to river (20%), slope (15%), basin (6%), flow accumulation (5%), flow direction (2%), drainage density (8%), watershed (3%) land use/land cover (3%), and Soil (9%) according to Julius Okpokwu & Igbokwe, (2019). The analysis reveals that the MAR contributed more to flooding than other factors considered in the model followed by distance to river, slope, soil and basin. These factors were reclassified to obtain values for each layer which was used in the weighted overlay model. Rainfall and slope influences the direction of the runoff or subsurface drainage. Furthermore, the slope has dominant control of the rainfall of stream flow, duration of flow and duration of infiltration process. Once the weight in each factor was determined, the multi-criteria analysis was performed to produce a flood-vulnerable area by using the GIS approach. (See figure 16).

Table 5: Percentage of Flood Vulnerable Zones. Source (computed by the Author).

Zone	**Area Covered (km^2)**	**Percentage (%)**

Highly Vulnerable	6	2
Vulnerable	148	39
Moderately Vulnerable	212	55
Less Vulnerable	15	4

It was also observed that some regions in Ogbaru Local Government Area falls within the highly vulnerable zone which was observed to be having a waterbody (River Niger), dense drainage system and a low topography. Table 5 described the areas and percentages covered by the vulnerable zones. It shows that the highly vulnerable zones covered (2 %), vulnerable (39%), moderately vulnerable (55%) while less vulnerable zone covered (4%). Due to the distance to river, land use/land cover along this area, heavy rainfall, soil and topography of the area, its most liable to flooding during rainy seasons when the river over flow its banks. Flooding causes not only economic loss, loss of lives but also causes various diseases such as waterborne disease, vector-borne disease, etc.). Based on the map, a total of thirty-six settlements were more prone to flood.

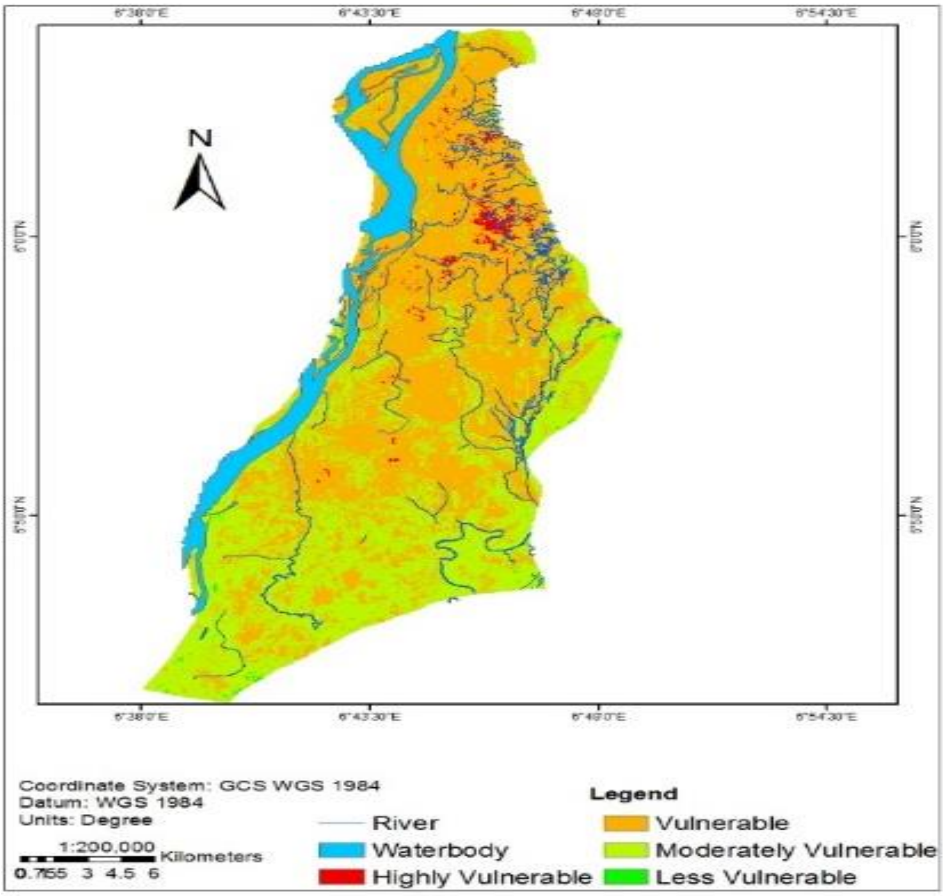

Figure 16: Flood Vulnerability of Ogbaru LGA, Anambra State, Nigeria

3.2 Flood Inventory Map

A flood inventory map of Anambra State from year 2018, 2020 and 2022 obtained from Nigeria Hydrological Service Agency (NIHSA) was used to validate the flood susceptibility map of Ogbaru LGA. The red colour in the map indicated flooded areas. It was observed that Ogbaru LGA was flooded in all the years sampled. This validated the susceptibility map which truly indicated Ogbaru LGA is an area susceptible to flood. The flood inventory map also agreed with the flood extent map generated from Boolean logical operation, which showed that the area was flooded at all the elevation sampled. See Figs 17, 18 and 19.

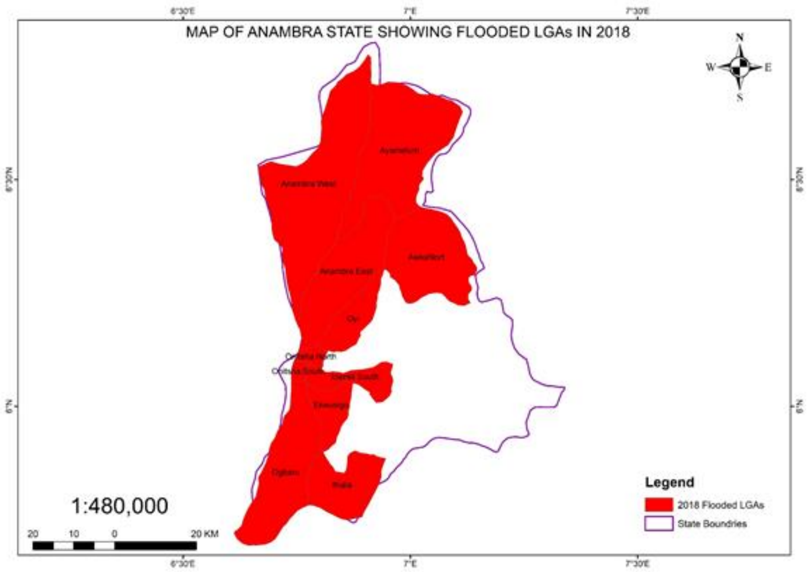

Fig 17: Anambra State showing flooded LGA's in 2018. Source: NIHSA

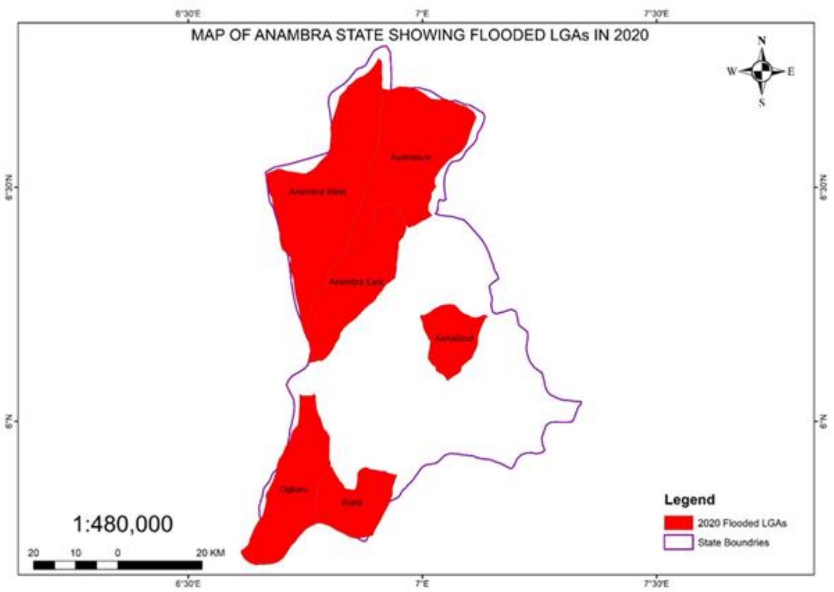

Fig 18: Anambra State showing flooded LGA's in 2020. Source: NIHSA

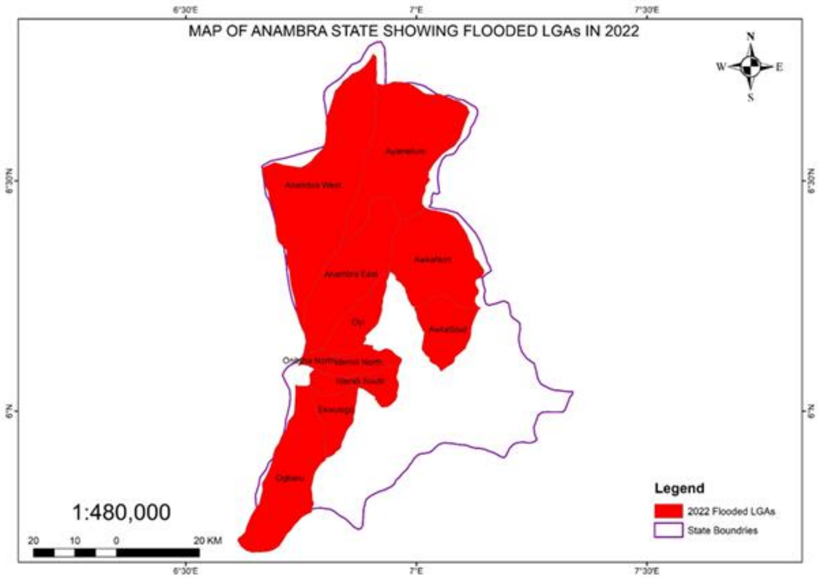

Fig 19: Anambra State showing flooded LGA's in 2022. Source: NIHSA

4. CONCLUSION

The concept of Remote Sensing (RS) and Geographic Information System (GIS) was employed in this research. Analytic Hierarchy Process (AHP) was used to perform the pairwise comparism of the ten criteria, after which weights were assigned to them by the AHP priority calculator software according to their order of importance and the magnitude of which they contribute to flood. Weighted Overlay model was used to generate the flood vulnerability map of Ogbaru LGA, using the ten flood conditioning parameter which includes; Slope, Flow Direction, Flow Accumulation, Basin, Watershed, Drainage density, Distance to River, Land Use/Cover, Rainfall, and Soil .

5. RECOMMENDATIONS

i. As part of early warning response to flood, the affected community should be supported by Anambra State Government and Local Government Councils in setting up functional mechanism for flood related emergencies to ensure timely evacuation when the need arises.

ii. In proffering lasting solution to the perennial flooding, the Federal Ministry of Power, Works and Housing, Federal Ministry of Water Resources as well as the Anambra State Ministry of Works should design and construct a sustainable dam, drainage and dredging of River Niger to achieve flood mitigation.

iii. Mapping of areas liable to flooding should be encouraged by Anambra State Government, Office of the Surveyor General of the Federation, Federal Ministry of Power, Works and Housing, Federal Housing Authority and all other related agencies for the purpose of city planning and infrastructural development. And for sensitization for people to seize constructing in water plains and across water channels.

iv. Anambra State Government should allocate budget to mapping sector, disaster and risk management for data driven decision making, intervention, prediction, control and mitigation of disasters.
v. Afforestation should be encouraged in Ogbaru LGA by Anambra State Government and Ogbaru Local Government Council. Maintaining of green environment and planting of trees is recommended to prevent total washing away by surface run-off thereby mitigating flood and also for erosion control.

REFERENCES

A. Bogoliubova & P. L. Tymków, 2014 *"Accuracy Assessment of Automatic Image Processing for Land Cover Classification of St. Petersburg Protected Area"*

A.L Adlyansah, R Hussain L & Hendra P, (2019). "*Analysis of Flood Hazard Zones Using Overlay Method with Figused-Based Scoring Based on Geographic Information Systems*": Case Study in Parepare City South Sulawesi Province. Remote Sensing Applications: Society and Environment 14(2019) 60-74.

Adeoye, N. O., Ayanlade, A. and Babatimehin, O., (2009). "*Climate change and menace of floods in Nigeria Cities*": Socio-economic implications, Advances in Natural and Applied Sciences, 3 (3), pp 369-377

A.K Etuonovbe, (2011) "*The Devastating Effect of Flooding in Nigeria*". Hydrography and the Environment, Innocent Chirisa, Zimbabwe. FIG Working Week 2011 Bridging the Gap between Cultures Marrakech, Morocco, 18-22 May 2011.

ArcGIS Resource Center. 2012. Desktop 10, (Online) Available at: http://arcgis.com/en/arcgisdesktop/10.0/help.

Basudeb Bhatta. (2011). "*Remote Sensing and GIS*" Second Edition, 442-444.

B-AIR (2020). https://www.listeorg/journals/index.php/JEDS/article/download/54802/56623

Britannica, (2011). https://www.britannica.com/science/Gleysol

Canada Centre for Remote Sensing (CCRS), (2007). "*Fundamentals of Remote Sensing*"

D. C. Tomlin, (1990). "*GIS and Cartographic Modelling*"

Department of Geography, Savitribai Phule Pune University, India (2019). "*Analysis of Flood Hazard Zones Using Overlay Method with Figused-Based Scoring Based on Geographic Information Systems*": Case Study. IOP Conference Series: Earth and Environmental Science. 280 012003

Ashraf Dewan, (2013). "*Floods in a megacity*": geospatial techniques in assessing hazards, risk and vulnerability: Springer.

Ejikeme, J. O., Igbokwe, J. I., Ezeomedo, I. C., Aweh, D. S. and Akinroye, R., (2015). "*Analysis of risks and impacts of flooding with satellite remote sensing*". Journal for Environment and Earth Science. 5 (4), ISSN: 2225 - 3948. Retrieved from: www.jiste.org

Endurance, .O, Olabanji, O. O & V N. Ojeh, (2019). "*Flood vulnerability of Afikpo South Local Government Area, in Ebonyi State, Nigeria*". Department of Road Research, Nigerian building and Road Research Institute, Ota Ogun State, Nigeria. International Journal of Environmental and Climate Change.

Environmental System Research Institute (ESRI) Copyright © 1995-2021.

Ezeokoli F.O, Okoye P.U. & Ugochukwu S.C, (2015). "Upshot of the 2012 flooding on structural components and fabrics of buildings at Ogbaru, Anambra State Nigeria". American Journal of Civil Engineering and Architecture, 2015, Vol. 3, No. 4, 129-136

Floodsite(2021).https://www.floodsite.net/juniorfloodsite/html/en/student/thingstoknow/hydrology/floodtypes.html

GSITI (2018). "ITEC 8th Course in Remote Sensing and Digital Image Processing for Geo-Scientists".

Guardian News: https://guardian.ng/news/flood-reptiles-invade-homes-in -anambra-community/ News Agency of Nigerian (NAN) September, 2020.

https://www.earthnetworks.com/flooding/

https://eartheclipse.com/ 2021

Haq, M., Akhtar, M., Muhammad, S., & Rahmatullah, J. (2012). "*Techniques of Remote Sensing and GIS for flood momitoring and damage assessment*": A case study of Sindh province, Pakistan. The Egyptian Journal of Remote Sensing Space Science, 15(2), 135-141

H. R Pourghasemi, B. Pradhan, C.Gokceoglu. (2012). *"Application of Fuzzy Logic and Analytical Hierarchy Process (AHP) to Landslide Susceptibility Mapping at Haraz Watershed, Iran"*. Natural hazards, 2012-Springer

Hwang & Yoon (1981). "*Multiple Attribute Decision Making: Methods and Applications*". Springer-Verlag, New York. http://dx.doi.org/10.1007/978-3-642-48318-9

Jaafari, A., Najafi, A., Pourghasemi, H., Rezaeian J., & Sattarian, A. (2014). "*GIS based frequency ratio and index entropy models for landslide susceptibility assessment in the Caspian forest, northern Iran*". International Journal of Environmental Science Technology, 11(4), 909-926.

Jenks (1967). *"Natural Breaks Classification"*

J.R. Anderson (1976). *"A land Use and Land Cover Classification System for Use with Remote Sensor Data"*

Julius,. O & Igbokwe (2019). "*Flood Vulnerability Assessment of Anambra State, using Flood Simulation Model*". Department of Surveying and Geoinformatics, Nnamdi Azikiwe University, Awka, Nigeria, 2019.

Kamonchat, .S, Aphittha, .Y, Sasithon, .C & Sarintip, .T, (2017). "*Assessment of Flood Hazard Areas using Analytical Hierarchy Process over the Lower Yom Basin, Sukhothai Province*". 7th International Conference on Building Resilience; Using scientific knowledge to inform policy and practice in disaster risk reduction, ICBR2017, 27 – 29 November 2017, Bangkok, Thailand. Department of Natural Resources and Environment, Naresuan University, Department of Civil Engineering, Naresuan University, Phitsanulok, Thailand.

Kazakis, N., Kougias, I., & Patsialis, T. (2015). "*Assessment of flood hazard areas at a regional scale using an index-based approach and Analytical Hierarchy Process*": Application in Rhodope-Evros region, Greece. J Science of the Total Environment, 538, 555-563.

Kishore, .C.S, Chranjit, .S & Laximikanta, (2020). "*Flood Susceptibility Mapping through the GIS-AHP Technique Using the Cloud*". Department of Agricultural Engineering, Institute of Agriculture, Visva Bharati, Sriniketan 731236, India. ISPRS Int. J. Geo-inf 2020, 9(12), 720:

Lee, M.J., Kang, J.E., & Jeon,S. (2012). *"Application of Frequency Ratio Model and Validation for Predictive Flooded Area Susceptibility Mapping Using GIS"*. In 2012 IEEE International Geoscience and Remote Sensing Symposium (IGARSS) (pp.895-898), Munich. https://doi.org/10.1109/igarss.2012.6351414

Malczewski, (2006). "*GIS Based Multicriteria Decision Analysis*": A Survey of the Literature. International Journal of Geographical Information Science, 20, 703-726

Matej Vojtek. (2019). "*Flood Susceptibility Mapping on a National Scale in Slovakia using Analytic Hierarchy Process*". Department of Geography and Regional Development, Faculty of Natural Sciences, Constantine the Philosopher University in Nitra, 94901 Nitra, Slovakia; jvojtekova@ukf.sk.February,2019.

Michael,. M. M & Michael Makonyo (2020). "*Flood susceptibility mapping using GIS and multi-criteria decision analysis*": A case of Dodoma region, central Tanzania. Remote Sensing Applications: Society and Environment (2020), doi: https://doi.org/10.1016/j.rsase.2020.100445.

Momoh & Bello. (2017). "*Geoinformatics for Socio- Economic Diversification and Environmental Management*". Publication of the Nigerian Cartographic Association (NCA).

NASA, 2009. Shuttle Radar Topography Mission. (Online) Available at: http://www.jpl.nasa.gov/srtm.

National Emergency Management Organization (NEMO) St. Vincent and the Grenadines, (2021). "*What Causes Flood*" nemo.gov.vc

Ndukwe (1997). "*Principles of environmental remote sensing and photo interpretation*". New concept publishers, Enugu State, Nigeria.

Ndukwe, (2001). "*Digital technology in surveying and mapping. Principle, application and legislative issues*". RhyceKerex Publisher. Enugu State, Nigeria.

Nwafor, J.C, (2006). "*Environmental Impact Assessment for Sustainable Development*". The Nigerian Perspective (first edition). EDPCA Publishers.

Nigerian Geological Survey Agency (NGSA,) (2021); "*Geological & Mineral Resources Map Album*", page 36.

NIHSA. (2018, 2020 & 2021). "*Flood Inventory Maps*"

NIHSA. (2021). "*Annual Flood Outlook (AFO)*"

NIHSA. (2021). "*Flood Management in Nigeria*".

NIHSA. (2020). "*Land Thema Bulletin*" Nov.2020 Vol.2

Ozoh Joan, (2020). "*Impact of flood crisis on the socio-economic livelihood of people in Nigeria*". Department of Economics, Nnamdi Azikiwe University, Awka Nigeria. International Journal of Economics, Commerce and Management.

PM New Nigeria, (2020). "*Situation during the 2022 flood in Ogbaru Local Government Area, Anambra State*".

Pradhan, B. (2009); *"Groundwater Potential Zonation for Basaltic Watersheds Using Satellite Remote Sensing Data and GIS Techniques"*. Central Eu-ropean Journal of Geosciences, 1, 120-129. https://doi.org/10.2478/v10085-009-0008-5

Pradhan, B. (2010); *"Flood Susceptibility Mapping and Risk Area Delineation Using Logistic Regression, GIS and Remote Sensing. Journal of Spatial Hydrology"*, 9, 1-18.

Saaty, T. L. (1977). "*A scaling method for priorities in hierarchical structures*". Journal of mathematical 727 psychology, 15(3), 234-281.

Saaty, T. L. (1980). "*The analytic hierarchy process*". (pp. pp. 287): New York: McGraw-Hill New York.

Saaty, T.L. 1987. "*The analytical Hierarchy Process*". - what it is and how it is used. Mathematical Modelling. 9, 161 – 176.

Saaty, T.L. 2008. "*Decision making with the analytic hierarchy process*". International Journal Service Science, 1, 83 – 98

Saaty, T. L., & Vargas, L. G. (2012). "*Models, methods, concepts & applications of the analytic hierarchy process*". (Vol. 175): Springer Science & Business Media.

Strahler, A. (1952). *"Dynamic Basis of Geomorphology"*. Geological Society of America Bulletin, 63, 923-938. http://dx.doi.org/10.1130/0016-7606(1952)63[923:DBOG]2.0.co;2

Subramanian, N., & Ramanathan, R. (2012). "*A review of applications of Analytic Hierarchy Process in operations management*". International Journal of Production Economics, 138(2), 215-241.

The Nigerian Journal of Cartography and GIS, (2013). Vol 8. No.1

Theeditor@punchng.com

ThisDay (2023). https://www.thisdaylive.com/index.php/2022/10/20/fg-lagbo-dam-not-responsible-for-massive-flooding-in-nigeria/

Tierney., (2001). "*Facing the Unexpected: Disaster Preparedness and Response in the United States, Natural Hazards and Disasters*". Joseph Henry Press, Washington.

U.E Akpovwovwo (2013). *"GIS Application to Soil Quality Assessment"* The Nigerian Journal of Cartography and GIS, Vol.8 No.1, p. 60,2013.

UNESCO. (2009). "*IWRM Guidelines at River Basin Level*": Part 2-2. The Guidelines for Flood Management. (PDF). Available at: http://www.unesco.org/water/news/pdf/part_22_guidelines_for_flood_management.pdf. (Accessed 10 August 2012).

UNESCO, WWWAP (2022). https://www.unesco.org/en/wwap

USGS. 2011. "*Flood Definitions*". (Online) Available at: http://ks.water.usgs.gov/waterwatch (Accessed 25 July 2012).

www.hindawi.com/journals/complexity/2020/4271376/

World Meteorological Organization (WMO), (2011) "*Annual Statement on the Status of the Global Climate*".

Zou, Q., Zhou, J., Zhou, C., Song, L., & Guo, J. (2013). "*Comprehensive flood risk assessment based on set pair analysis-variable fuzzy sets model and fuzzy AHP*". J Stochastic Environmental Research Risk.