Flood Vulnerability Study of Oha River Basin, Nigeria

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ABSTRACT

The increasing episodes of flood bringing about enormous damage to lives and properties in different parts of South-western region of Nigeria, served as a key rationale for this study. It thus mapped out a pragmatic plan to measure the spatial attributes and factors aggravating the impact of flood in Oha River basin, one of the major sub-basins in the region, as a contribution to the basic data sets, frame, and baseline information required to mitigate the devastating impact of flood in South-western Nigeria. The study delineated Oha river basin as a sub-basin from the regional basin, generated some thematic datasets (such as drainage, elevation/height, and soil) and produced flood vulnerability rating map of the basin. Multi-Criteria Decision Methods (MCDA) technique was employed using an indigenous software, SAVEMACE, to model the vulnerability case while Geographic Information System (GIS) environment was used to prepare the data and also present the visualisation of the vulnerability results. The factors considered in MCDA analysis were Elevation, Distance to Stream, Slope, Rainfall, Land Use Land Cover (LULC) and Soil. The results from the flood vulnerability modelling showed that 4.34% of the study area was least vulnerable to flooding, 37.28% was found marginally vulnerable, 55.73% was moderately vulnerable while 2.65% was found to be Highly vulnerable to flooding. The established degree of vulnerability of Oha basin to flood disaster would provide a framework for effective resources allocation to flood monitoring and control in the area.

Keywords: *Oha basin; Nigeria; MCDA; GIS; Flood; Vulnerability*.

INTRODUCTION

Disasters arising from floods have, over the years, accounted for thousands of deaths and huge damage to properties across the world; such mishaps had displaced tens of thousands of people from their habitations and enforced the destruction of their means of livelihood [1] and [2]. Developing countries and poor communities are prominently vulnerable. Flood in the context of hazard (potential danger) or natural disaster could be expressed as water inundation, which could be explained as an accumulation of overwhelming quantity of water, in a wrong place and poses danger to the surroundings [3]; Reference [4] defined flood as uncharacteristically soaring flow of a water-body that makes the water overruns its natural or man-made boundaries; Flood could also be put as the movement of water beyond the enabled-volume of its passage [5]. The probable climate changes are foreseeable to cause a rise in the intensity and rate of rainfall, which might bring about greater severe and extensive floods and other related natural disasters in the vulnerable places around the globe [6].

In Nigeria, flooding is a familiar occurrence. In the last forty eight years, there have been incidences of flooding in various parts of the country. These could be urban floods, flash floods, back-swamp floods, channel floods, and coastal inundation, among others [7] Amangabara and Obenade, 2015). The most recent with a very devastating impact was that of 2012 which, according to the National Emergency Management Agency (NEMA), affected more than three-quarters of the States (30 out of 36 States) in the country [8] and 7 million people in those States [7]. Efforts to mitigate the impact of flood in Nigeria include the establishment of Federal agencies and parastatals such as NEMA and Nigerian Meteorological Agency (NiMet). NEMA has the mandate to provide relief for victims of tragic events like

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flooding while NiMet was commissioned to give real-time information about rainfall, its intensity and the likely events that may follow weather extremities through their early warning system. These bodies have over time discharge their duties; however, it could be observed that damages to lives and properties still remain high in times of flood.

The increasing episodes of flood bringing about enormous damage to lives and properties in different parts of South-western Nigeria, served as a key rationale for this study. It thus mapped out a pragmatic plan to measure the spatial attributes and factors aggravating the impact of flood in Oha River basin, one of the major sub-basins in the region, as a contribution to the basic data sets, frame, and baseline information required to mitigate the devastating impact of flood in South-western Nigeria. Studies on flood vulnerability in South-western Nigeria are still of great relevance in the national development; it would reveal the level of exposure of an area or community to a likely event of flood in that environment. Such studies are necessary for effective and efficient disaster management.

Analytical Hierarchy Process (AHP) is one of the Multi-Criteria Decision Methods (MCDA). It uses hierarchical structures to represent an identified problem and develop priorities for options based on the evaluation of the user [9]. AHP has been productively used in handling various flooding challenges [10] and [11]. AHP was used in this study to allocate weights to the flood causative elements or factors. A multiple pairwise comparisons based on a standardized comparison scale of nine levels is then used to obtain the pairwise comparison matrix; Table 1 illustrates the nine-point scale. Pairwise judgements are made based on the best information available and the knowledge and experience of experts. The local priority (weight) for a criterion was computed from a pairwise comparison matrix by normalizing the points in the columns (divide a cell value by the sum of a column) and averaging the normalized points in the row of the criterion.

TABLE 1: NINE-POINT SCALE

Saaty's Scale of Relative Importance	Definition	Linguistic Variables
	Just equal	Just equal
1	Equal importance	Least importance
3	Moderate importance of one over another	Moderate importance
5	Essential or strong importance	Essential importance
7	Demonstrate importance	Demonstrate importance
9	Extreme importance	Extreme importance
2,4,6,8	Intermediate values	When compromise is needed
Reciprocals of above non zero numbers	If an activity has one of the above numbers (e.g., 3) compared with a second activity, then the second activity has the reciprocal value (e.g., 1/3) when compared to the first	

Source: Adapted from [12].

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The consistency of the comparisons is evaluated by calculating a Consistency Ratio (CR). If the CR is equal to or less than 0.1, the comparison is considered consistent, otherwise, it would be reviewed. The CR is defined by equation 1:

$$CR = Consistency\ index / Random\ Index \ \ldots . (1)$$

The Random Index (RI) refers to a randomly generated reciprocal matrix from the 9-point scale and can be obtained by referring to the RI table. Reference 13 provides a function of n in the relationship as shown in Table 2.

The consistency index (CI) is defined as:

$$CI = (\lambda_{max} - n)/(n - 1) \ \ldots \ldots \ldots (2)$$

Where,

λ_{max} is the largest Eigenvalue derived from the comparison matrix, and;

n is the number of criteria.

The procedure of AHP used in this study could be summarized into four steps: construction of the decision hierarchy; determining the relative importance of factors and sub-factors; evaluating each alternative and calculating the overall weight regarding each factor; and checking the consistency of the subjective evaluations. A similar procedure was used in [11], [14] and [15].

TABLE 2: RANDOM INDEX TABLE

n	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45

'n' represent the number of criteria

Source: Adapted from [13]

This research attempts to fill the existing gap of knowledge by the provision of geospatial information necessary in understanding the mechanism of flood in one of the sub-basins of the South-western region in Nigeria as it relates to drainage network, land use land cover, terrain, rainfall, slope and soil. These factors were incorporated into the Suitability and Vulnerability Modeling and Computation Environment (SAVMACE), indigenous software developed in COPINE for flood vulnerability modeling. SAVMACE has AHP as one of its major algorithms. The resultant output and models underpin the role of channel network on the geo-hydrological behaviour of the river basin in relation to the intensity and rate of flood evaluations.

STUDY AREA

The study area, Oha River basin, could be found in the South-western Nigeria, being a sub-basin in the region; it lies across Ondo and Edo States. The area cuts across three Local Government Areas, which are Idanre (of Ondo State), Ovia South-west and Ovia North-east Local Government Areas (of Edo State). The area is located between Latitude 6° 32’ 34.65’’ and 7° 3’ 41.56’’ North and Longitude 5° 8’ 5.55’’ and 5° 27’ 56.64’’ East, with a total land area of about 1,191 km^2 [16], (Fig. 1). The climate of the Southern Nigeria is tropical and could be basically described by the dry and wet seasons. The regions is characterised by strong rainfall occurrences during the rainy season from March to October with annual rainfall amounts of above 2,000 mm, and could even be up to 4,000 mm and more in the Niger Delta [17]. The dry season is linked with the Northeast trade wind from the Sahara Desert while the wet season is in connection with the Southwest monsoon wind originating from the Atlantic Ocean [18].

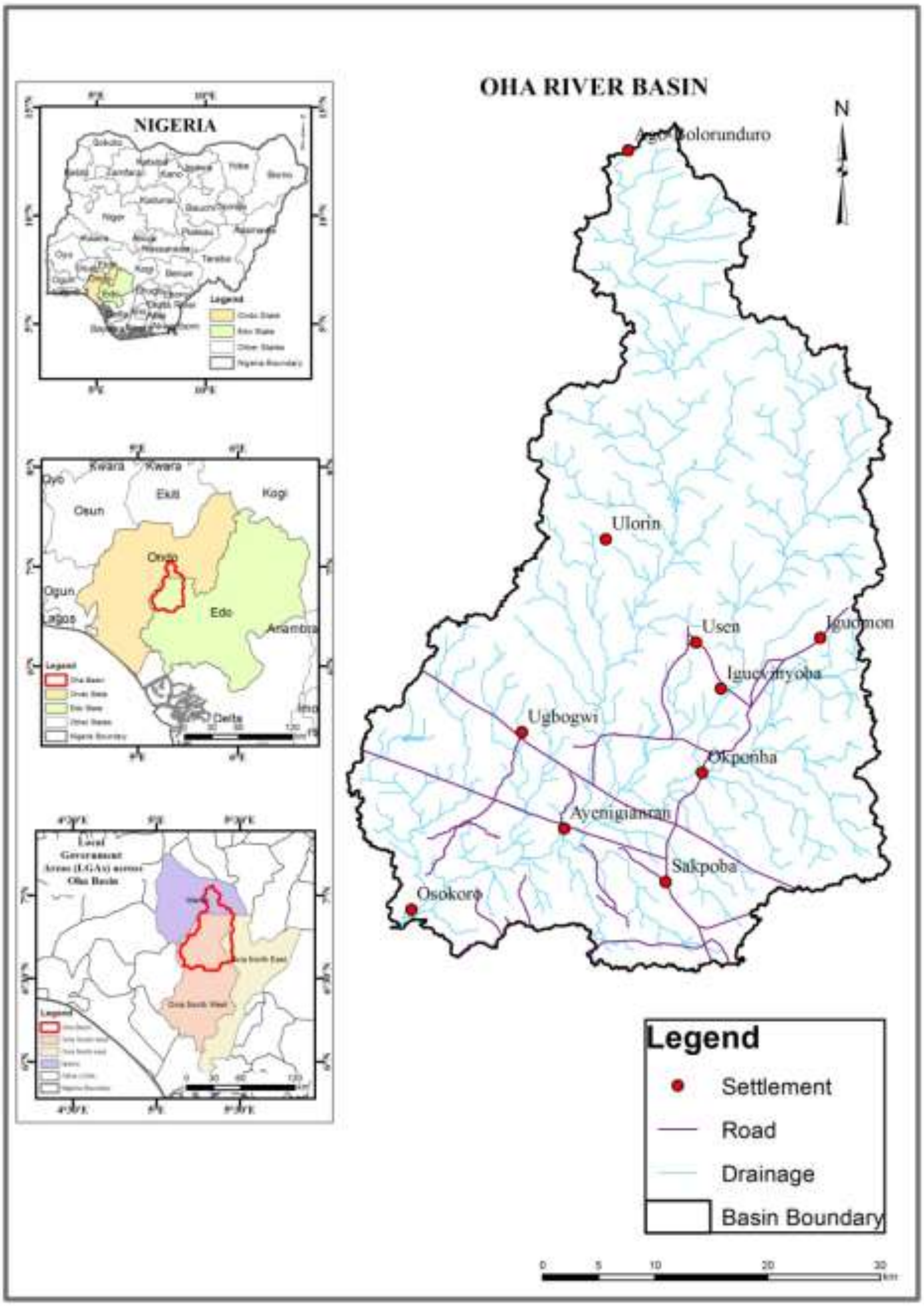

Figure 1: **Map of the Study Area**

Fundamentally, the vegetation in Southwest Nigeria consists of swamp forest (saltwater and freshwater mangrove) in the coastal area of Lagos and Ogun States; followed by tropical rainforest in the hinterland. The low land in the forest stretches inland to Ogun and parts of Ondo State, while the secondary forest is towards the northern boundary where the derived southern Savannah exists. Nevertheless, it is important to note that vegetation characteristics are significantly influenced by the rainfall pattern, parent materials and human factors since some areas that were, naturally, part of the forest belt have been replaced with wooded savannah due to periodic clearing of the forest for cultivation purpose [19].

The whole landscape of South-western Nigeria is underlain by old metamorphic rocks, protruding to form high hills in many locations. The land surface is undulating and the topography is characterized by vast plains broken by steep-sided inselbergs (dome-shaped hill), occurring singly or in groups. The inselbergs are particularly numerous in Ondo State. The Idanre Hills, which attained the height of 900 m (3,000 ft), are the most prominent inselbergs in the basin. Though crude oil is now by far the most important source of government revenue in Nigeria, about 70% of the labour force in southwest Nigeria is employed in agriculture. Most south westerners are still peasant farmers producing their food crops and deriving income from one or more cash crops, as well as from the sale of surplus food crops. The main food crops grown in the southwest are yam, cassava, rice, and maize. Market gardening is important around the major towns where the increasing number of educated citizens has created a great demand for crops like cassava, maize, yam, palm oil, garri, rice, etc. The establishment of large modern poultry farms in the outskirts of the major towns is a relatively recent development in the region.

METHODOLOGY

A. Material requirements

Data used for this study and their sources are summarised in Table 3. Geographic Information System (GIS) Softwares used for the analysis include ArcMap 10.3 and ENVI 4.7; Others are MS-Excel 2007 and SAVEMACE.

B. Data preparation

Topographic and Administrative maps of Nigeria covering the study area served as the base map. The Topography maps, being in analogue format, were converted into TIFF computer image format through scanning process and imputed into ArcMap for geo-referencing to allow compatibility and comparison with other data. River names were afterward extracted from the topographic maps.

The Spatial Analyst Tools of the ArcMap 10.3 were used on the SRTM (Digital Elevation Model) data to generate hydrological attributes such as, flow direction, flow accumulation, streams/drainage and to delineate the drainage basin for the study area. The drainages were ordered by Strahler model [20]. The 3D Analyst Tools of the software were used to generate the primary terrain feature, which is Triangulated Irregular Network (TIN) from the DEM data, which facilitated the generation of the elevation (or height) data for the study area.

Table 3: Summary of Data Requirements

Data	Source	Resolution	Type
1. Digital Elevation Model (DEM) Satellite Imagery	Shuttle Radar Topography Mission (SRTM) Archive	30m	Digital
2. Earth Observed Satellite Imagery	Landsat 8 ETM, (Year 2020) United States Geological Survey (USGS) Archive	32m	Digital
3. Soil	*Wageningen, Netherlands (Archive)*		Digital
4. Topography	Office of the Surveyor General of the Federation (OSGOF), Nigeria.	1:50,000	Analogue
5. Administrative map	Office of the Surveyor General of the Federation (OSGOF), Nigeria.		Digital
6. *Rainfall*	NiMet, Nigeria		Ground-based

Full Gaussian Supervised classification, using the maximum likelihood algorithm in ENVI, was used to generate five Land Use Land Cover (LULC) classes from the earth observed satellite imagery. The five LULC classes generated for the study area include Built-up area, Bare surface, Cultivation, Vegetal cover and Rock outcrop.

C. Flood vulnerability modelling

The flood vulnerability model was developed in SAVMACE with the use of MCDA techniques. At the factors level, the relative contribution of each identified factor to flood vulnerability was specified using AHP. Furthermore, the AHP module in the software was employed to generate the relative weight for each factor by comparing the factors with one another on the ordinal scale of importance or significance to flooding, ranging from 1 to 9. The ordinal comparisons, of one factor to another, were performed with the Geometric Mean method incorporated into SAVMACE. Moreover at the class level, within each of the factors, the relative weights of the classes or sub-factors were modelled using Weighted Linear Combination (WLC). The relative weights at the classes or sub-factors were obtained utilizing Sequential Numerical Ranking and Rationing.

The factors considered for this flood vulnerability study, in decreasing order of importance, were Elevation, Distance to Stream, Slope, Rainfall, Land Use Land Cover (LULC) and Soil. The factors were subjected to the AHP procedures, specifying their relative importance to one another. The operation produced the following weights for the factors respectively: 0.3931(Elevation/Height), 0.2637(Distance to stream), 0.1530 (Slope), 0.0964 (Rainfall), 0.0574 (Landuse landcover) and 0.0365 (Soil); the consistency ratio obtained was less than 0.1. Considering the number of factors used in this modelling, the ratio obtained shows that the relative importance specifications of the AHP were consistent. The classes within each factor were identified and weighted according to their levels of seriousness or significance. The results of the vulnerability percentage computation were then classified to indicate four (4) levels of vulnerability. The Level is as follows: 0-25% is Less vulnerable, 26-50% is Marginally vulnerable, 51-75% is Moderately vulnerable, and 76-100% is Highly vulnerable. The results of the modelling were eventually brought to be visualized and symbolized in the ArcMap environment.

RESULTS AND DISCUSSION

A. *Terrain, Drainage and Soil*

The minimum height in the Oha River basin was found to be 15m while the maximum height was 450m. The highest drainage (stream) order gotten from Oha River basin, using [20] ordering system, was 5; while the total number of drainages found in the basin was 451. The length and number of drainages per order are given in Table 4. The elevation (height) layout of the basin is presented in a 3D format with the ordered streams in Figure 2. Three types of soil were found predominant in the study area; they include Acrisols, Lixisols and Nitisols (Figure 3).

Table 4: Details of Drainages in Oha basin

Order	Number of Drainages	Length of Drainage (km)	% of Drainage Length
1	336	443.61	48.22
2	87	266.36	28.96
3	24	99.53	10.82
4	3	81.24	8.83
5	1	29.18	3.17
Total	451	919.92	100.00

B. *Land Use/ Land Cover of Oha Basin*

Five LULC classes were identified in this study. The classification analysis shows that Built up accounted for 41.31 km^2, Bare surface had 19.91 km^2, Cultivated land occupied 1128.77 km^2, suggesting agriculture is an important economic activity in the study area. Vegetal cover had 0.01 km^2 while Rock outcrop covered 1.1 km^2 (Figures 4).

C. *Flood vulnerability distribution*

The results from the flood vulnerability modelling showed that 51.69 km2 (4.34%) of the study area was found Least vulnerable to flooding, 444.04 km^2 (37.28%) was found Marginally vulnerable, 663.8 km^2 (55.73%) was Moderately vulnerable while 31.56 km^2 (2.65%) was found to be Highly vulnerable to flooding occurence. The vulnerability map shown in Figure 5 shows few settlements in the affected areas to avoid clumsiness. More list of the affected settlements, by category of vulnerability, is given in Table 5 with greater attention on the adversely affected ones. The flood vulnerability results of this study showing a profund tendency of flood in the areas of low elevation supports [21] that floods basically occur in areas of flat and low topology.

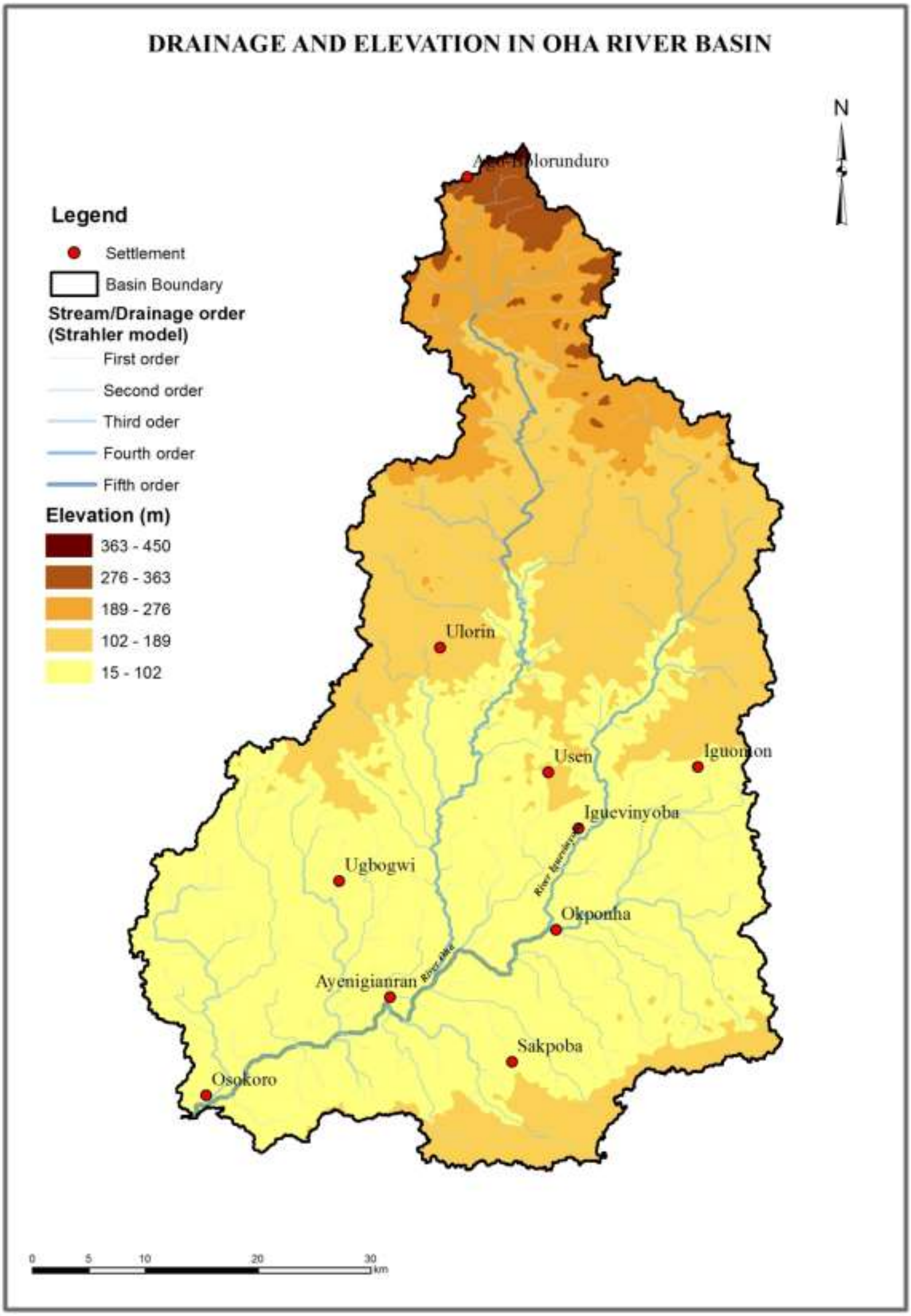

Figure 2: Map of Drainage and Elevation of Oha Basin

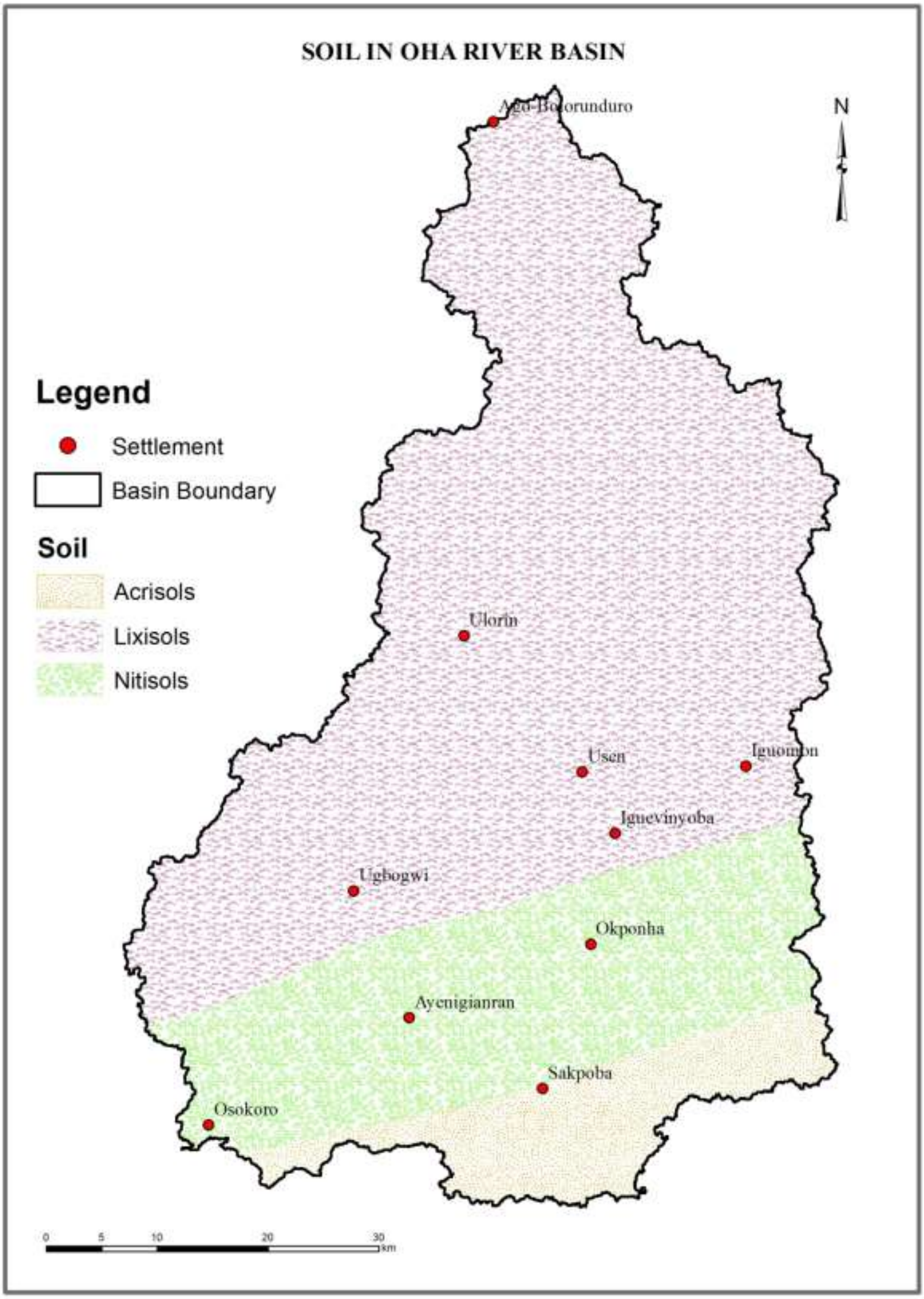

Figure 3: **Map of Soil types in Oha Basin**

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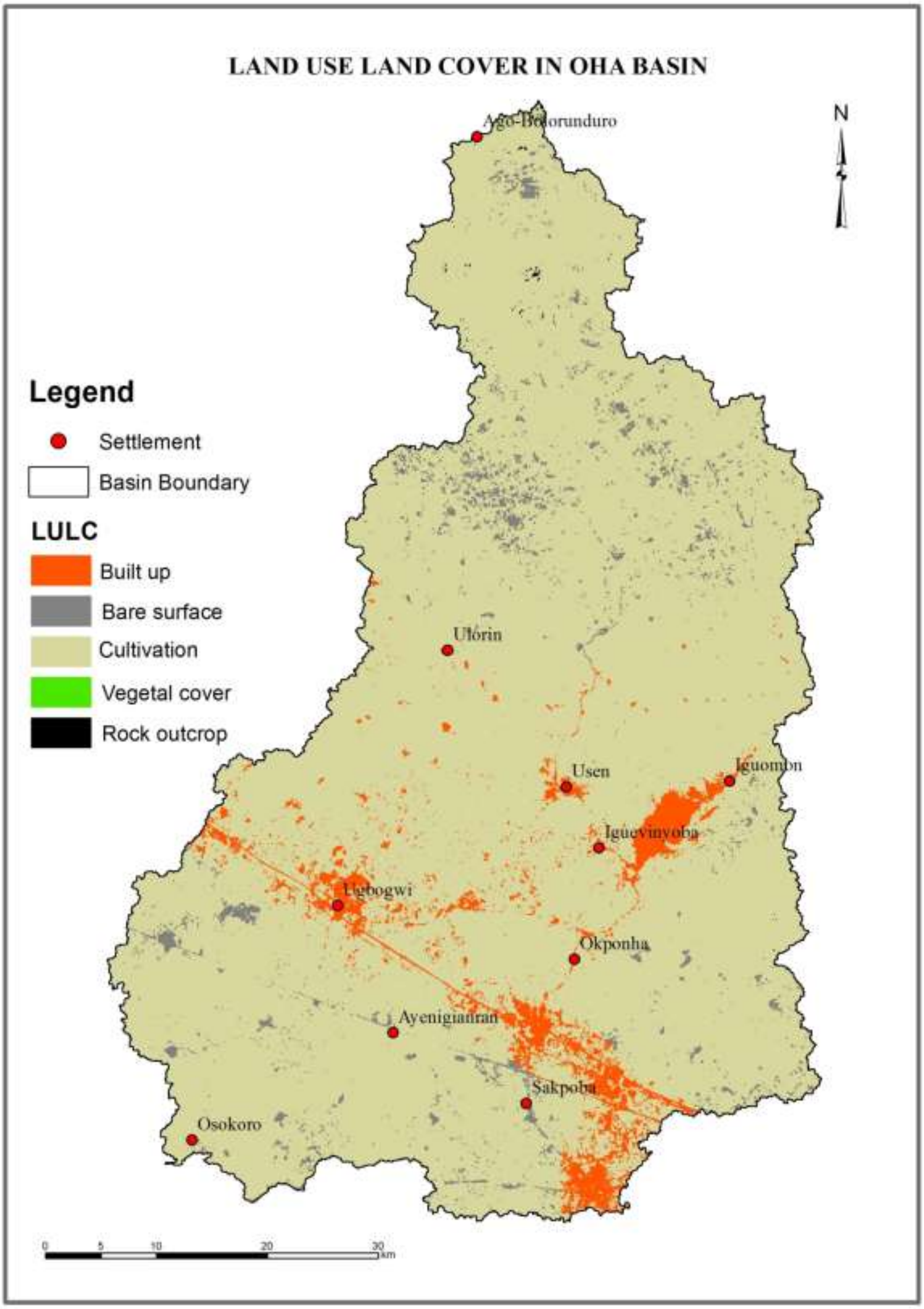

Figure 4: Map of Land Use Land Cover (LULC) in Oha Basin

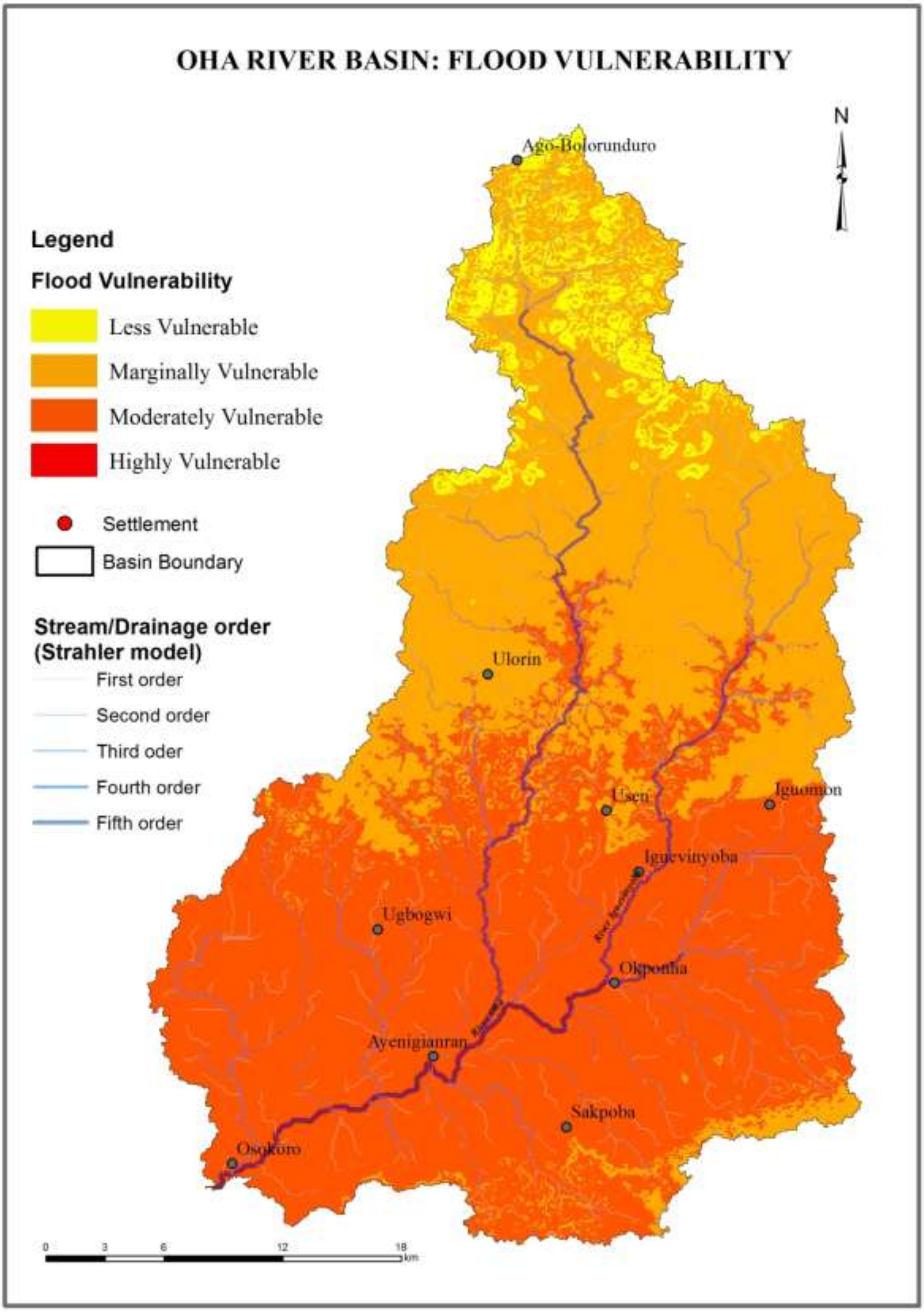

Figure 5: Map of Flood Vulnerability in Oha Basin

Table 5: Settlements in Oha River Basin by Vulnerability Class.

S/n	Less Vulnerable	Marginally Vulnerable	Moderately Vulnerable	Highly Vulnerable
1.	Ago-Bolorunduro	Okuzuwa	Aligholo	Okponha
2.		Ulorin	Ayenigianran	
3.			Esi	
4.			Igbogo	
5.			Iguatakpa	
6.			Iguatakpo	
7.			Iguevinyoba	
8.			Iguobazowa	
9.			Iguobazuwa	
10.			Iguogun	
11.			Iguomon	
12.			Igwogun	
13.			Ikoha	
14.			Kaloko	
15.			Lakolako	
16.			Okada	
17.			Okha	
18.			Okokpon	
19.			Okoro	
20.			Okoro	
21.			Okozo	
22.			Osokoro	
23.			Sakpoba	
24.			Ugbogwi	
25.			Usen	
26.			Usenin	

CONCLUSION

The research attempts to fill the existing gap of knowledge in the provision of geospatial information necessary in understanding the mechanism of flood in Oha River basin, one of the sub-basins in the Southwestern region of Nigeria as it relates to drainage network, climate, land use land cover, terrain, rainfall, slope and soil. About 58% of the basin was found to be significantly vulnerable to flood occurrence. The established degree of vulnerability of Oha River basin to flood disaster would provide a framework for effective resources allocation to flood monitoring and control.

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