Assessment of Flood Vulnerability Levels in the Lower Orashi River, Niger Delta Region, Nigeria

Abstract

Flooding is one of the most frequent and widespread of all environmental hazards and of various types and sizes. This study investigated the flood vulnerability levels in the lower Orashi River, Niger Delta Region, Nigeria. The study considered the landuse, soil texture, elevation, slope, stream power index (SPI), rainfall, drainage density and proximity to river channels as factors determining flood. The components of these factors were reclassified as lowly, moderately and highly vulnerable areas with assigned numbers 1, 2 and 3 respectively. All the maps were overlaid using the UNION module for the final flood vulnerability levels. Descriptive statistics and inferential statistics were used in the data analysis. Results showed that the very low flood vulnerability levels covered spatial extent of 244.4 sq km (7.31%), low flood vulnerability covered 901.31 sq km (26.95%), moderate flood vulnerability level 1240.18 sq km (37.08%), high flood vulnerability level 846.47 sq km (25.31%) and very high had 112.11 sq km (3.35%).It can be concluded that more than 65% of the entire lower Orashi River are highly and moderately vulnerable to flood. It is therefore recommended among others that periodic studies should be carried out in lower Orashi River to monitor the factors that can cause flood in the area.

Keywords: Flood, Environmental hazards, Vulnerability, Lower Orashi, Drainage, Landuse/Land cover, UNION module

Introduction

The past two decades have seen a significant upsurge in the frequency of flooding on a global scale [11]. The Intergovernmental Panel on Climate Change (IPCC) confirmed that flood vulnerability would most likely increase in line with increasing rainfall events [13]. The occurrence of flooding around the world is fast becoming normality with about 70 million people exposed to flood risk and at least 800 million people susceptible [19]. Its impacts are as well immeasurable. For example, in the United States, floods destroy property worth US$6 billion and kill 140 people annually [12].

Flood is an extreme weather event naturally caused by rising global temperature which results in heavy downpour, thermal expansion of the ocean and glacier melt, which in turn results in rise in sea level, thereby causing salt water to inundate coastal lands. Floods or flood waters are temporary inundation of normally dry land areas from the overflow of inland or tidal waters, or from the unusual and rapid accumulation or runoff of surface waters from any source onto lands that are used or usable by man and not normally covered by water [18]. Flood is one of the natural environmental hazards ravaging the landscape of mankind over the years and whenever flood occur, they result in the loss of properties, lives, destruction of farmlands etc. in most towns in the world [14].

According to [9]Nigeria has got her own share of flood disasters, which is evident in the recent widespread devastating flood disaster that hit the country cutting across major cities in about 31 states in the country from June to September 2012. The worst affected states are those that are at the borders of the Niger- Benue River and those around the Niger Delta area, they are, Adamawa, Taraba, Benue, Niger, Kogi, Anambra, Bayelsa, Delta, Edo, Rivers, Cross River and Akwa Ibom. This flood incident has been characterized as the most devastating since the last 40 years. The flood submerged houses, severed transportation routes throughout the affected areas.Flood risk and vulnerability are increasing due to changes in rainfall pattern, increased frequency of extreme events, changes in land use and development in flood prone areas as a result of socio-economic demand. Human lives, property, environment, and socioeconomics are at increasing risk due to flooding [5]. There are different methods to quantify flood hazard, vulnerability, and risk. The vulnerability is best defined as an aggregate measure of human welfare that integrates environmental, social, economic and political exposure to a range of potential harmful perturbations. The vulnerability is a multi-layered and multidimensional social space defined by the determinate, political, economic and institutional capabilities of people in specific places at specific times [17]. In the same vein, analyzing vulnerability is a fundamental component of flood risk management. Historical records reveal that several approaches have been used to assess flood vulnerability [4]. Thus, it is essential to get several dimensions for a precise comparative assessment of vulnerability which necessitated the need for the use of geospatial techniques in flood hazard, risks and vulnerability assessment.
The term terrain evaluation is used to denote the assessment of properties of terrain as a whole, whether over large or small areas, that are applicable to any given purpose. The term is used mostly when areas are being assessed for engineering or urban and regional planning purposes, but it is not restricted to these purposes. Forms of terrain evaluation have been applied to similar assessments for rural purposes [8]. According to [21], three elements are important in terrain analysis and these are: interpolation of digital elevation models (DEMs); (2) DEM generalization and denoising; and (3) computation of morphometric variables through calculating partial derivatives of elevation.
It is based on this background that the study seeks to assess flood vulnerability levels of lower Orashi River, Rivers State, Nigeria.

Materials and Methods

The study was carried out in the lower Orashi River, Niger Delta Region, Nigeria. The Orashi River bifurcates into two at Egbema in Rivers State with the larger right portion flowing through Eluku before bifurcating again into two and emptying into the Gulf of Biafra. The Orashi Region is home to over 35% of the oil wells in the Niger Delta States of Imo and Rivers. The Orashi River is located geographically within latitude $4^0\ 47^{'}\ 20^{''}$ N and $5^0\ 06^{'}\ 20^{''}$ N and longitude $6^0\ 24^{'}\ 40^{''}$ N and $6^0\ 43^{'}\ 40^{''}$ N (Figure 1).

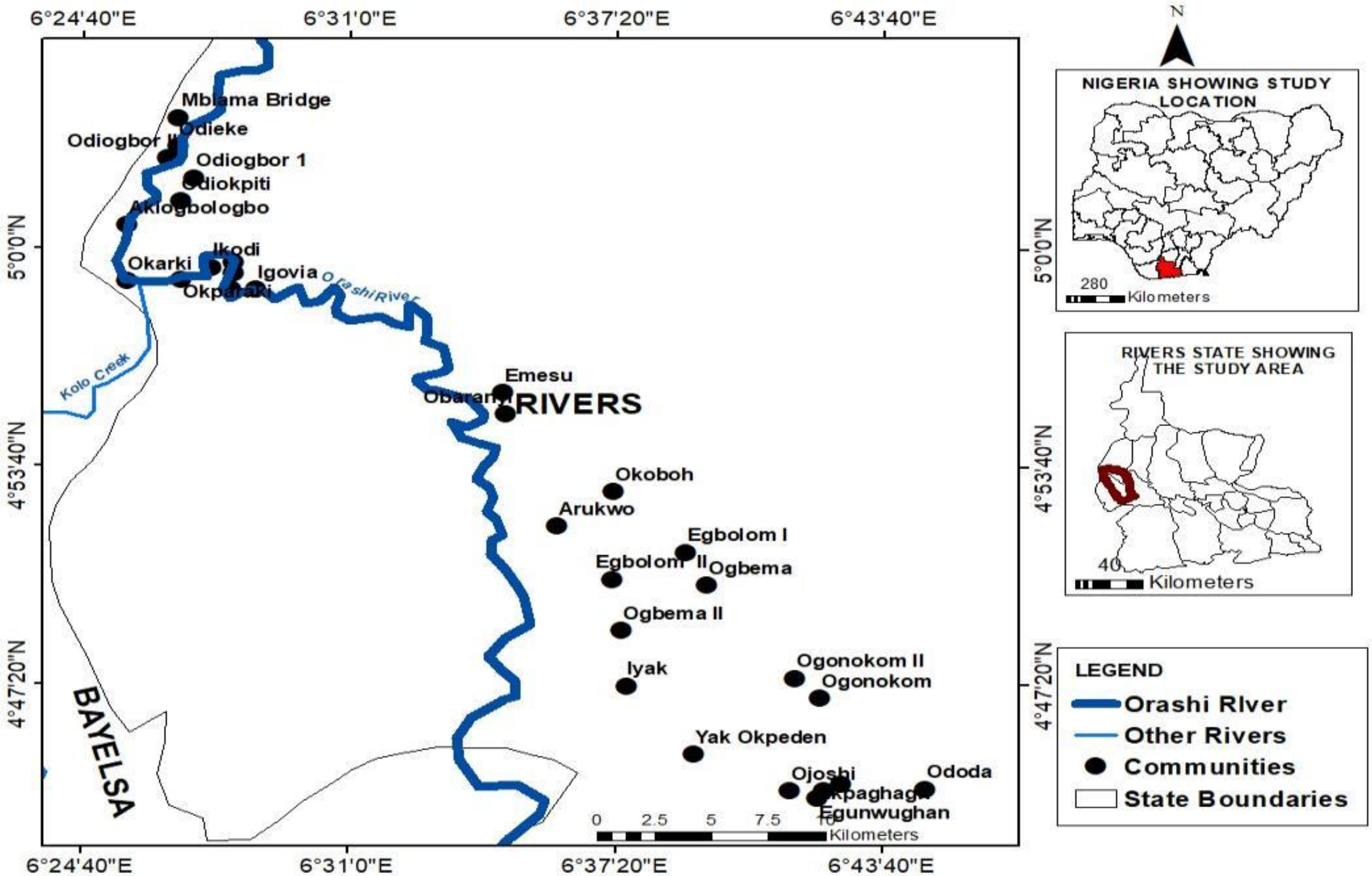

Figure 1: Orashi River and Surrounding Communities
Source: Adapted from Google Earth (2021)

The study area features a tropical monsoon climate, designated by the Koppen climate classification as "Af", and it is mostly found in the southern part of the country. This climate is influenced by the monsoons originating from the South Atlantic ocean, which is brought into the country by the (maritime tropical) MT air mass, a warm moist sea to land seasonal wind. Its warmth and high humidity gives it a strong tendency to ascend and produce copious rainfall, which is a result of the condensation of water vapour in the rapidly rising air [12]. The tropical monsoon climate has a very small temperature range. Then temperature ranges are almost constant throughout the year. For example, Warri Town in the southern part of Nigeria, records a maximum of 28 °C (82.4 °F) for its hottest month while its lowest temperature is 26 °C (78.8 °F) in its coldest month. The temperature difference of Warri town is not more than 2 °C (5 °F) [12]. The study area experiences heavy and abundant rainfall. These storms are usually convectional in nature due to the regions proximity, to the equatorial belt. The annual rainfall received in this region is very high, usually above the 2,000 mm (78.7 in) rainfall totals giving for tropical rainforest climates worldwide. Over 4,000 mm (157.5 in) of rainfall is received in the coastal region of Nigeria around the Niger Delta area. Bonny town found in the coastal region of the Niger delta area in southern Nigeria receives well over 4,000 mm (157.5 in) of rainfall annually. The rest of the southeast receives between 2,000 and 3,000 mm (118.1 in) of rain per year [12]. The coastal sedimentary basin of the region has been the scene of three depositional cycles. The first began with a marine incursion in the middle Cretaceous and was terminated by a mild folding phase in Santonian time. The second included the growth of a proto-Niger delta during the late Cretaceous and ended in a major Paleocene marine transgression. The third cycle, from Eocene to Recent, marked the continuous growth of the main Niger delta. A new threefold lithostratigraphic subdivision is introduced for the delta parts subsurface, comprising an upper sandy Benin formation, an intervening unit of alternating sandstone and shale named the Agbada formation, and a lower shaleAkata formation. These three units extend across the whole delta and each ranges in age from early Tertiary to Recent. They are related to the present outcrops and environments of deposition. A separate member of the Benin formation is recognized in the Port Harcourt area. This is the Afam clay member, which is interpreted to be an ancient valley fill formed in Miocene sediments. Subsurface structures are described as resulting from movement under the influence of gravity and their distribution is related to growth stages of the delta [21]. The study area is well drained with both fresh and salt water. The salt water is caused by the intrusion of seawater inland, thereby making the water slightly salty. The vegetation of the study area consists mainly of forest swamps. The forests are of two types, nearest the sea is a belt of saline/brackish Mangrove swamp separated from the sea by sand beach ridges within the mangrove swamp. Numerous sandy islands occur with fresh water vegetation. Fresh water swamps gradually supersede the mangrove on the landward side. Some of the forest zone's most southerly portion, especially around the Niger River and Cross Riverr deltas, is mangrove swamp. North of this is fresh water swamp, containing different vegetation from the salt water mangrove swamps, and north of that is rain forest [7].According to [6], the region is endowed with mosaic of fragile sensitive and diverse ecosystem. The major ecological zones of the region include mangrove forest and coastal vegetation zone, freshwater swamp forest zone, lowland rainforest zone and the derived savannah zone found in the northern part of the region. The primary economic activities in most rural communities in the around the Orashi River include peasant farming, petty trading and fishing, shifting cultivation (Slash and burn), which involves cultivating a piece of land for a number of years and then abandoning it for a more fertile land is traditionally practised in the area. Some of the cash crops grown in the study area include oil palm (*Elaeisguineensis*), cacao (*Theobroma cacao*), cassava (*Manihot esculenta*) and rubber (*Herea brasiliensis*) [17]. The study adopted mixed research design which included both descriptive and longitudinal research designs. A pre-field survey was carried out which involved site visitation of the study area which is the lower Orashi River segment in River State. The survey exercise aided in establishing points of references for the study. The possibility of carrying out an empirical survey of this nature was also justified through the reconnaissance survey exercises. The primary data sources involved data gathering of points of references for the study with the help of a hand-held global positioning system (GPS). It also involved the measurements in situ of lower Orashi river physical attributes like depth, width, and flow velocity. The study shall download imageries of the Orashi region in order to delineate and determine the land use/land cover systems in the area, as this information aided the study in the mapping analyses for the study. The secondary data sources included obtaining satellite imageries of the study area from the United States Geological Survey (USGS) 2022. The land uses imageries, DEM data; monthly rainfall data of the study region for a period of 40 years till 2022was obtained from WorldClim Historical data (between 1982 and 2022). The soil texture types for the study shall be obtained from FAO Digital Soil Map. The details of the all data types and their sources are presented on Table 1.

Table 1: Details of Data Types and Sources

Type of Data	Data Description	Nature of Data	Sources
DEM	SRTM Digital Elevation Model (DEM) for 2020 (0.00083m resolution) Grid Format	Geotiff Raster Format	USGS/NASA SRTM data (Reuter et al, 2007)http://srtm.csi.cgiar.org
Soil Data	FAO Digital Soil map of the World (DSMW)	Shapefile Vector Format	Food and Agriculture Organisation of the United Nations (2020)
Landuse/Land cover	Landsat Imagery	Geotiff Raster Format	United States Geological Survey Earth Explorer (www.usgs.gov)

Annual Rainfall	WorldClim Historical Climate Data for Monthly Precipitation (between 2018 and 2022).	Geotiff Raster Format	Downscaled from CRU-TS-4.03 by the Climatic Research Unit, University of East Anglia, using WorldClim 2.1 (Harris et al., 2017; Fick and Hijmans, 2017)

Land use/land Cover Analysis

The land use/land cover was determined from the imageries to be downloaded. This was followed by classification into different land use types. The supervised classification method was employed because of its high accuracy and the knowledge of the training areas. The coordinates of the points of relevance/references for the study for each land use class were collected with the aid of GPS during the reconnaissance survey for ground truthing purposes. This was done to aid the supervised classification method to be applied for land use analysis. Thereafter sets of pixels were identified and the datasets were classified into land use classes/types.

Elevation

The Shuttle Radar Topography Mission (SRTM) is an international Research effort that obtained DEM on a near-globe scale from 56^0 S to 60^0 N to generate the most complete high resolution digital topographic database of the earth. The SRTM for the study shall be rectified and projected into UTM, WGS 1984 datum, 32N zone projection system in order to minimize errors in the ArcGIS 10.5 platform. This aided the study to determine the varying elevation of the study region.

Slope Mapping

The slope map was used to indicate based on topographic features showing changes in elevation which aided the study in analyzing the flow of the river. The projected SRTM data were utilized in order to generate the slope in degrees for the study.

Soil Texture Classifications

The soil texture maps was provided using the FAO Digital Soil Map of the World (DSMW) Shapefile (2020) whereby the zone of interest (Orashi River) was captured over respective area and their soil data was clipped to the study area in ArcGIS 10.5 platform. This information aided the study in determining soil textural classes which can determine the rate of infiltration or percolation of runoff in the study area and this was useful for exposing flood prone areas in the study.

Rainfall Data

The rainfall data were obtained from the WorldClim website Historical Climate Data for Monthly Precipitation between 1982 and 2022. The rainfall characteristics quantify the influence of precipitation on the amount and rate of runoff factor on soil in the study area (Praveen,

&Sharma, 2019). The amount of rainfall thus had several implications on flood potentiality of the study region.

Flood Vulnerability Maps

The flood potentiality levels were assigned values 3, 2, 1 to high vulnerability, moderate vulnerability and low vulnerability respectively by applying the ranking method to the factors. Using these values, the landuse vulnerability map, drainage network vulnerability map, soil texture vulnerability and elevation vulnerability map were overlaid in ArcGIS 10.7 with the use of UNION MODULE. Reclassification method was applied to have very high vulnerability, high vulnerability, moderate vulnerability, low vulnerability and very low vulnerability. The output of these maps shall be regarded as the flood prone zones in the study area considering the land use, proximity to river channels (drainage network), and elevation and soil texture maps of the area. Spatial query in ArcGIS 10.5 was used to determine the vulnerability levels and their spatial extents.The study employed the descriptive statistics for data presentation for the study. The descriptive statistics were in form of percentages, tables, charts, diagrams and maps to explain data obtained as regards the objectives of the study. Inferential statistics involving analysis of variance (ANOVA), correlation and regression analysis were employed for data analysis. It is as well considered that results and findings were presented using tables, graphs and charts.

Results and Discussions

Land use/ land cover maps of the river and its surrounding areas

The landuse/land cover analysis can be viewed in Table 2, and Figure 2 which is meant for the landuse/land cover vulnerability analysis which is also reflected as part of is contained in Table 2. The landuse/land cover analysis reveals that waterbodies, swamp forest/riparian vegetation, built up area, thick vegetation/plantation, farmlands/sparse vegetation and mangrove were the major landuse/land cover in the study area. It is further revealed that waterbodies covered 8.04% (240.41 sq km), swamp forest/riparian vegetation had a spatial extent of 578.07 sq km (19.33%) while the built up area had a spatial extent of 284.34 sq km (9.51%). It was discovered that thick vegetation/plantation had spatial coverage of 805.82 sq km (26.95%) while farmlands/sparse vegetation covered 275.66 sq km (9.22%) and mangrove covered 805.72 sq km (26.95%). The landuse/land cover vulnerability showed that thick vegetation/Plantation was categorized to be of low flood vulnerability which covered 805.82 sq km (26.95%). The farmlands/spare vegetation and swamp forest/riparian vegetation are considered to be of moderate flood vulnerability and these landuse/land cover had spatial coverage of 853.73 sq km (28.55%) while waterbodies, built up area and mangrove were categorized to be of high flood vulnerability and they covered 1330.47 sq km (44.50%).

Table 2: Landuse/Land cover Analysis for Flood Vulnerability in Lower Orashi River

Landuse	Spatial Extent (sq km)	Percentage (%)	Vulnerability Assigned Values	Vulnerability Interpretations

Waterbodies	240.41	8.04	3	High Vulnerability
Swamp Forest/Riparian	578.07	19.33	2	Moderate vulnerability
Built Up Area	284.34	9.51	3	High Vulnerability
Thick Vegetation/Plantation	805.82	26.95	1	Low Vulnerability
Farmlands/Spare Vegetation	275.66	9.22	2	Moderate vulnerability
Mangrove	805.72	26.95	3	High Vulnerability
Total	2990.02	100.00		

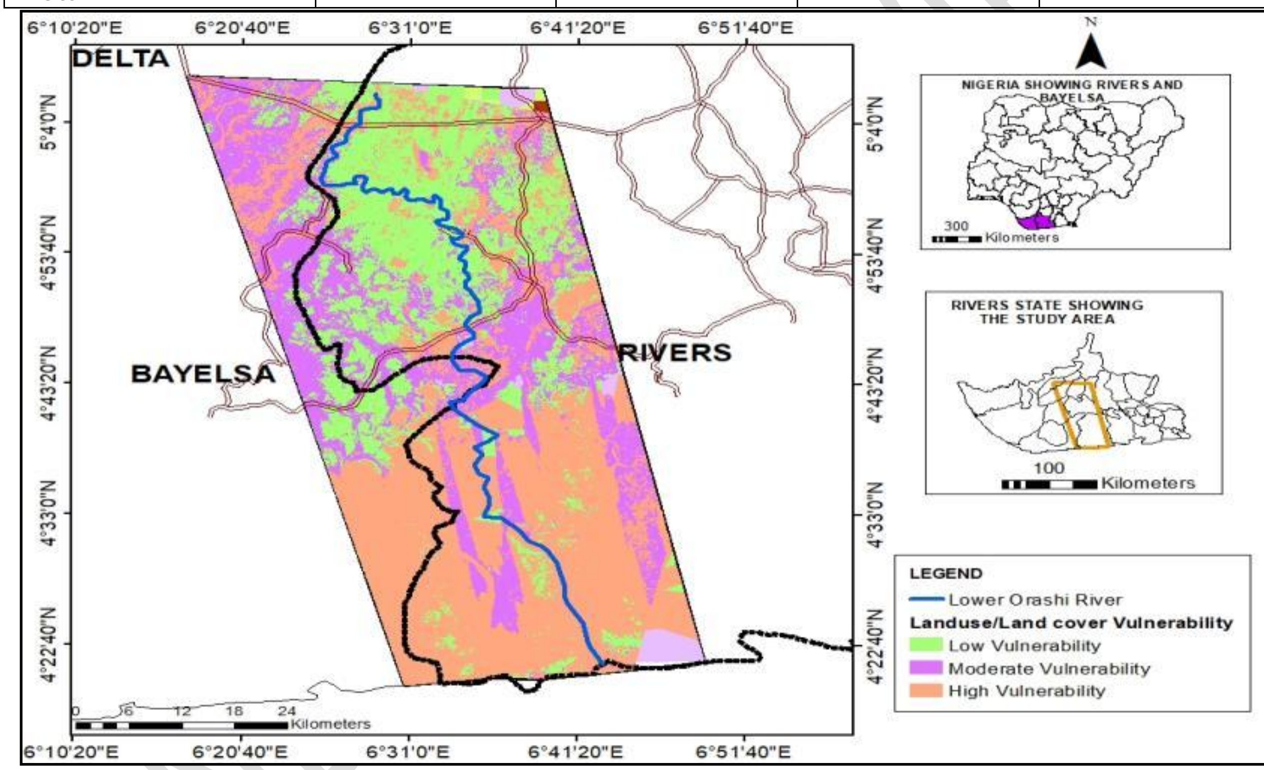

Figure 2: Landuse/Land cover Flood Vulnerability of Lower Orashi River

Soil texture and rainfall characteristics of the study area

The soil texture of the study area showed presented in Table 3 and Figure 3 reveal that Medium texture had 1731.44 sq km (53.37%), Coarse texture had 6.93 sq km ((0.21%), and Fine texture had 890.76 sq km (27.46%). The medium and fine texture dominated the study area and this shows that more proportions of the runoff may not percolate and lead to flooding in the Lower Orashi River. This is highly reflected in the flood vulnerability in Figure 6 which had 53.37% and high vulnerability had 46.41% (1505.58 sq km) categories highlighted for soil texture. The soil texture analysis showed that more of the study area was into moderately flood vulnerability. Although, the highly vulnerability was also significant.

Table 3: Soil Texture

Soil Texture	Spatial Extent (sq km)	Percentage (%)	Vulnerability Assigned Values	Vulnerability Interpretations
Medium Texture	1731.44	53.37	2	Moderate vulnerability
Coarse	6.93	0.21	1	Low Vulnerability
Water	614.82	18.95	3	High Vulnerability
Fine Texture	890.76	27.46	3	High Vulnerability
Total	3243.95	100.00		

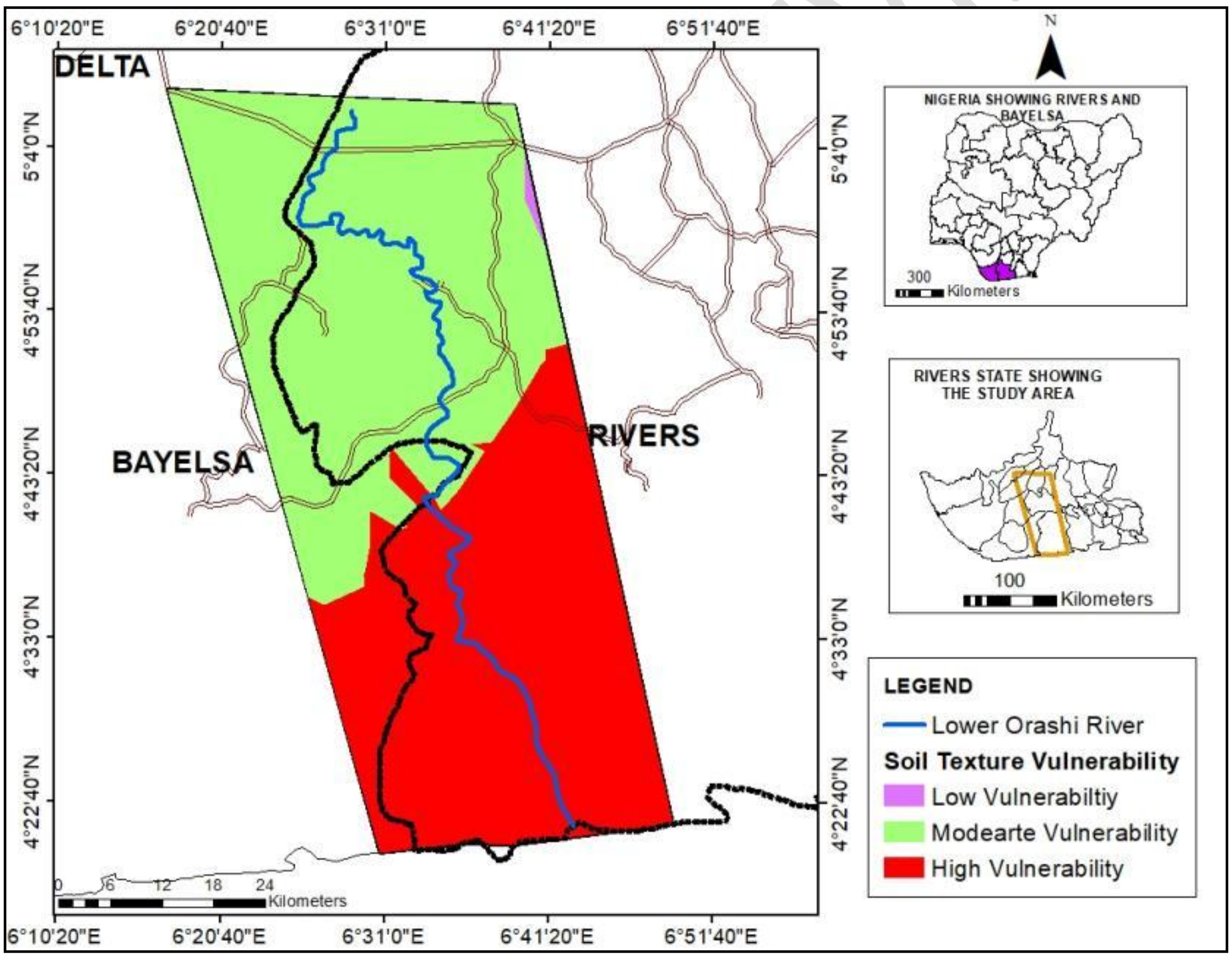

Figure 3: Soil Texture Flood Vulnerability of Lower Orashi

Rainfall vulnerability to flooding

Random sampling points of 100 points were generated in ArcGIS 10.7 which covered the entire study area and these points were used to extract the values of rainfall from the precipitation data generated from the historical gridded shapefiles obtained from https://gis.ucar.edu/gis-climatedata website which covers the entire world. This was downscaled to the study area using the random sampling points generated and the values extracted were used for the interpolation of other unsampled areas using IDW interpolation method. The rainfall data from NIMET that covers Port Harcourt and the environs were also used to see the deviation through remote sensing. The rainfall variation within the study area is presented in Table 4 while Figure 4explained rainfall vulnerability. The analysis showed that more than 60% of the study area experience rainfall between 3769.30 mm and 3872.71 mm. The rainfall intensity in the study area showed that the entire Lower Orashi River was highly rated for flood vulnerability based on the rainfall intensity. However, the rainfall variability between 1982 and 2018 showed that rainfall was increasing at the rate of 3.7682 annually with 2.25% coefficient of determination (Figure 5).

Table 4: Rainfall (mm) in the Study Area

Rainfall Classes (mm)	Spatial Extent (sq km)	Percentage (%)	Vulnerability Levels	Vulnerability Interpretation
3769.30-3785.49	1799.44	55.47	3	High Vulnerability
3785.50-3815.78	159.63	4.92	3	High Vulnerability
3815.79-3837.19	13.55	0.42	3	High Vulnerability
3837.20-3852.34	26.28	0.81	3	High Vulnerability
3852.35-3872.71	53.07	1.64	3	High Vulnerability
3872.72-3902.48	1191.98	36.74	3	High Vulnerability
Total	3243.95	100.00		

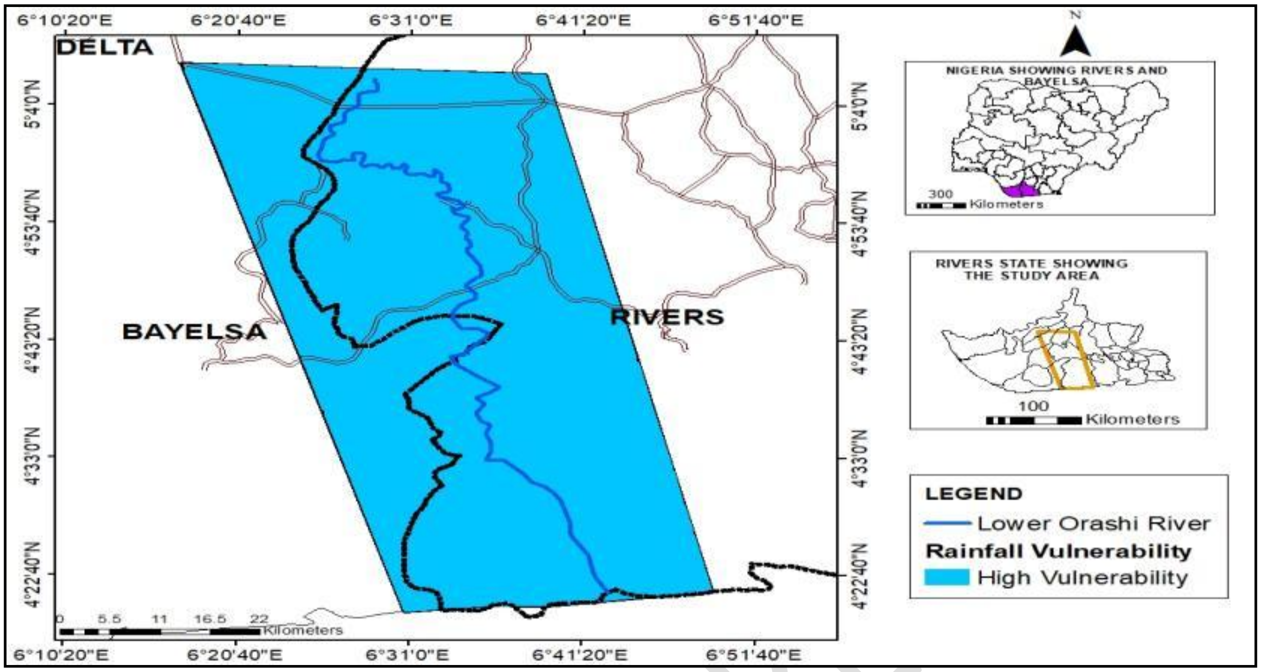

Figure 4: Rainfall vulnerability in the study area

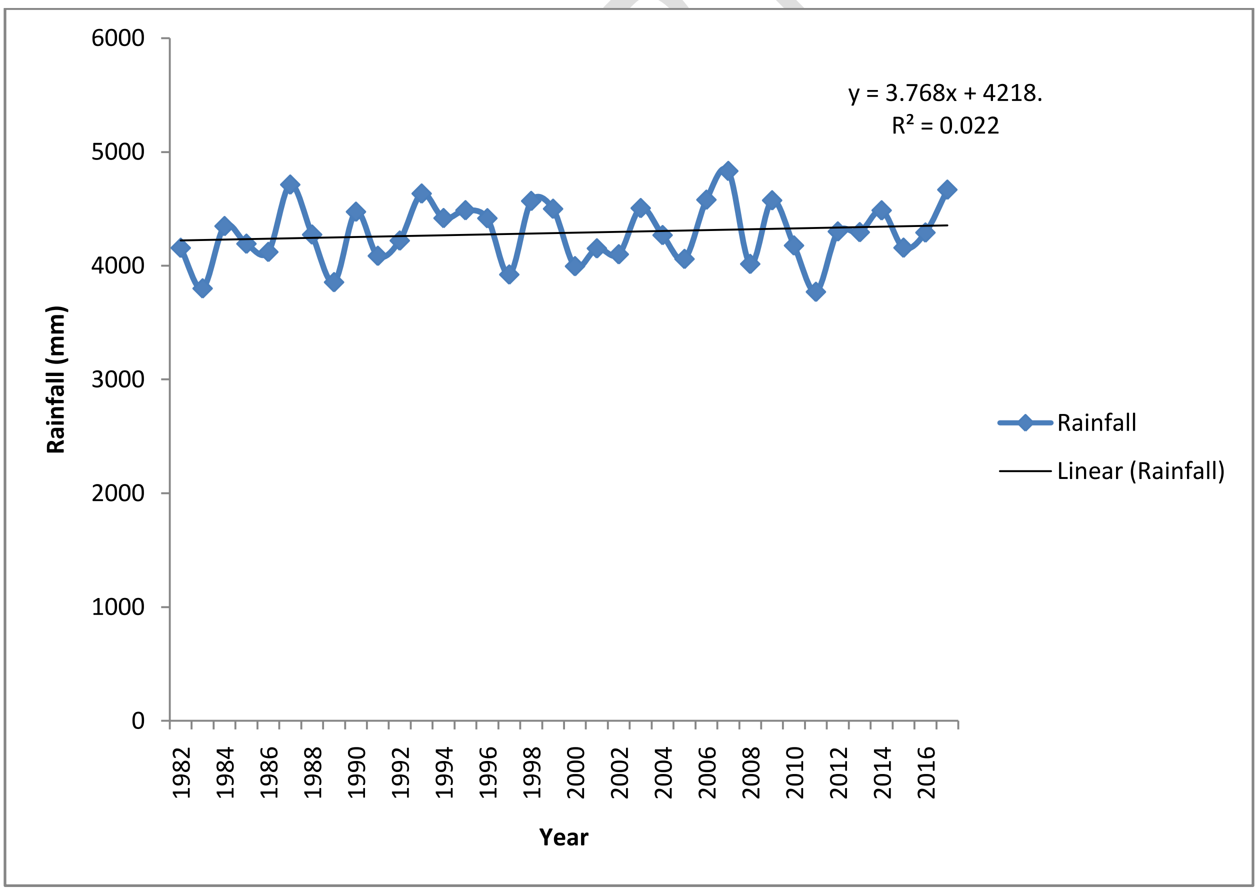

Figure 5: Trend Surface Analysis of Rainfall Distribution from 1982 to 2018 from NIMET

Nearness to Active River Channels

Talking about the proximity to active river channel, it is shown in Table 5 and Figure 6 which showed the three scenarios used were 500m, 1000m and 1500m and it is discovered that the 500m that is regarded to be highly vulnerable, had 773.86 sq km (35.95%), the moderate vulnerability had 714.96 sq km (33.22%) while the low vulnerability covered 663.62 sq km (30.83%). The proportion of the study area that was moderately and highly vulnerable to flooding was more than 60% suggesting that the study area must be rich in drainage density.

Table 5 Proximity to Active Channels in the Study Area

Distance from the Active River Channels (m)	Spatial Extent (sq km)	Percentage (%)	Vulnerability Levels	Vulnerability Interpretation
500	773.86	35.95	3	High Vulnerability
1000	714.96	33.22	2	High Vulnerability
1500	663.62	30.83	1	Low
Total	2152.44	100.00		

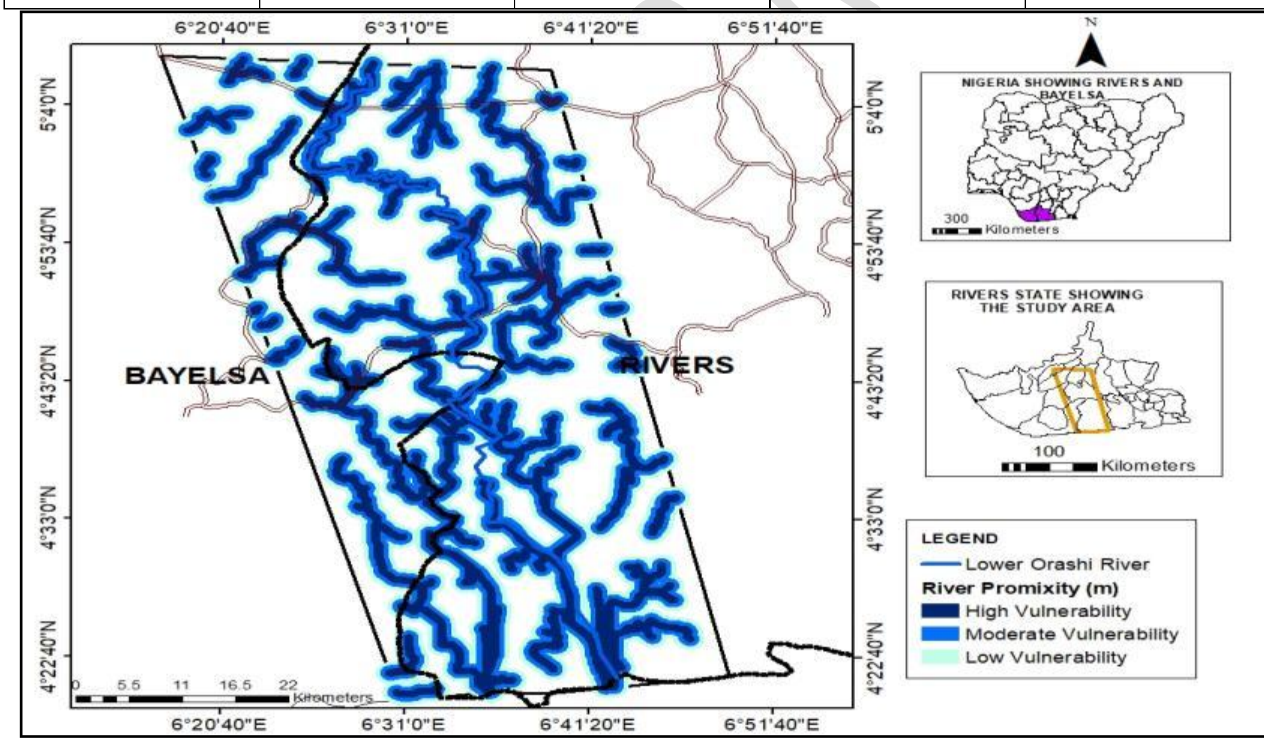

Figure 6: Flood Vulnerability based on River Proximity

Drainage Density Flood Vulnerability

It is discovered that Table 5 and Figure 6 present the drainage density classes and flood vulnerability analysis and it is also shown in the analysis that the drainage density ranged from 0 to 91.78 sq km. In the class between 0 and 14.75 sq km had spatial coverage of 456.38 (14.08%), drainage density class between 14.76 and 26.63 sq km had 696.78 sq km (21.50%), between

26.64 and 37.07 sq km had 826.1 sq km (25.49%), between 37.08 and 47.86 sq km had 745.04 sq km (22.99%), between 47.87 and 62.62 sq km had 419.45 sq km (12.94%) while between 62.63 and 91.78 sq km drainage density had 97.23 sq km (3.00%). Considering the flood vulnerability based on drainage density in Figure 7 and numerically expressed in Table 7, the low vulnerability classes covered 35.58 %, moderate vulnerability class covered 48.48% and low vulnerability covered 15.94%. This analysis showed that more than 60% of the entire study area is prone to moderate and high flood vulnerability based on drainage density. This is a fact that is also in support of the poor drainage type experienced in the Niger Delta Area.

Table 6: Drainage Density (sq km)

Drainage Density Classes	Spatial Extent (sq km)	Percentage (%)	Vulnerability Levels	Vulnerability Interpretation
0-14.75	456.38	14.08	1	Low Vulnerability
14.76-26.63	696.78	21.50	1	Low Vulnerability
26.64-37.07	826.1	25.49	2	Moderate Vulnerability
37.08-47.86	745.04	22.99	2	Moderate Vulnerability
47.87-62.62	419.45	12.94	3	High Vulnerability
62.63-91.78	97.23	3.00	3	High Vulnerability
Total	3240.98	100.00		

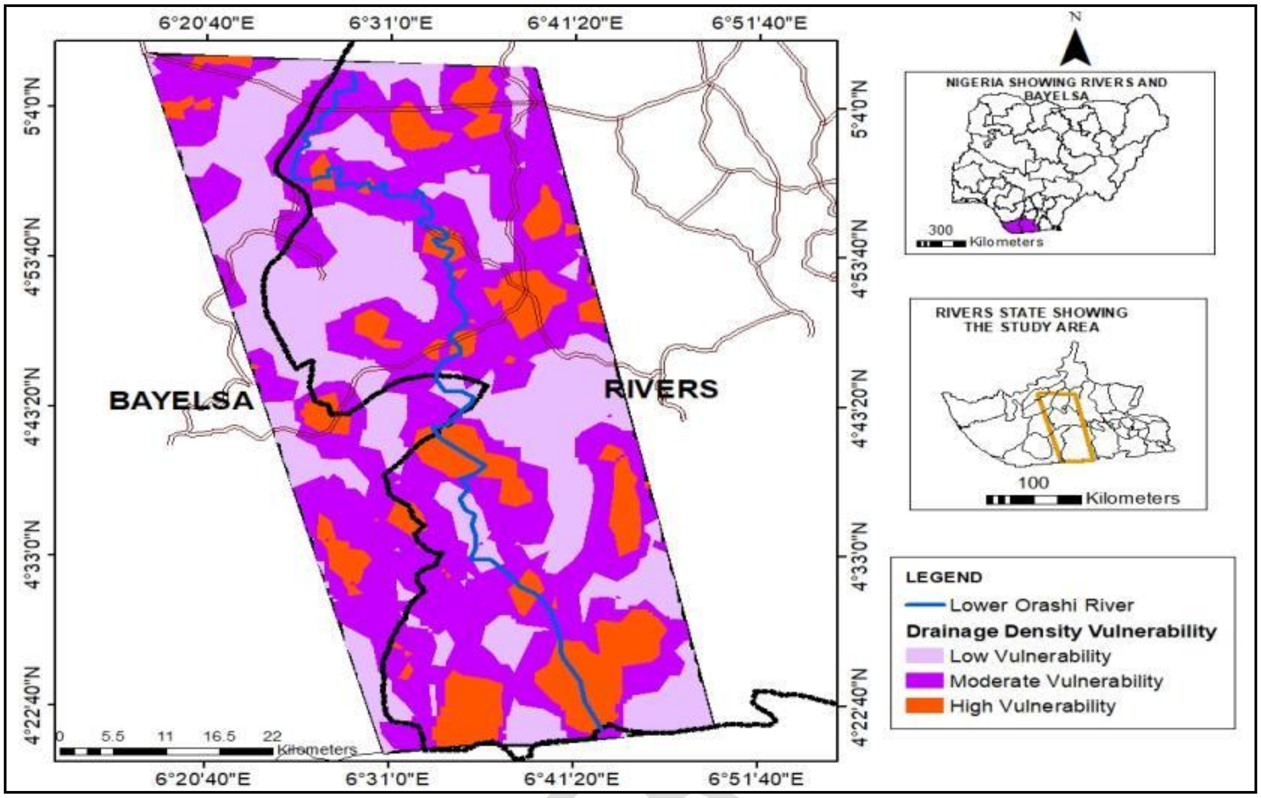

Figure 7: Flood Vulnerability Levels based on Drainage Density

Variability of topography and changes in elevation (slope, flow direction, flow accumulation, and stream power index)

The flood vulnerability level based on elevation is shown in Table 7, while Figure 8 presents the elevation vulnerability to flood. Analysis shows that the places in the study area within the 0 to 5m relief were 655.80 sq km (23.06%), between 5.01 and 10m was 636.93 sq km (22.40%), between 10.01 and 16m was 339.48m (11.94%), between 16.01 and 20 m was 591.50 sq km (20.80%) while those between 20.01 and 24m had 466.46 sq km (16.40%) and places greater than 24m had 153.58 sq km (5.40%). It is thus shown that the high vulnerability zone ranged between 0 and 10m and it covered 1292.73 sq km (45.46%). The moderate vulnerability based on elevation covered 930.98 sq km (32.78%) while the low vulnerability covered 620.04 sq km (21.80%). The analysis thus shows that more than 50% of the study area was moderately and lowly vulnerable to flood based on elevation.

Table 7: Relief (m) of the Study Area and the Vulnerability of Relief to Flood

Relief (m)	Spatial Extent (sq km)	Percentage (%)	Vulnerability Assigned Values	Vulnerability Interpretations
0-5	655.80	23.06	3	High Vulnerability

5.01-10	636.93	22.40	3	High Vulnerability
10.01-16	339.48	11.94	2	Moderate Vulnerability
16.01-20	591.50	20.80	2	Moderate Vulnerability
20.01-24	466.46	16.40	1	Low Vulnerability
24.01-40	153.58	5.40	1	Low Vulnerability
Total	2843.75	100.00		

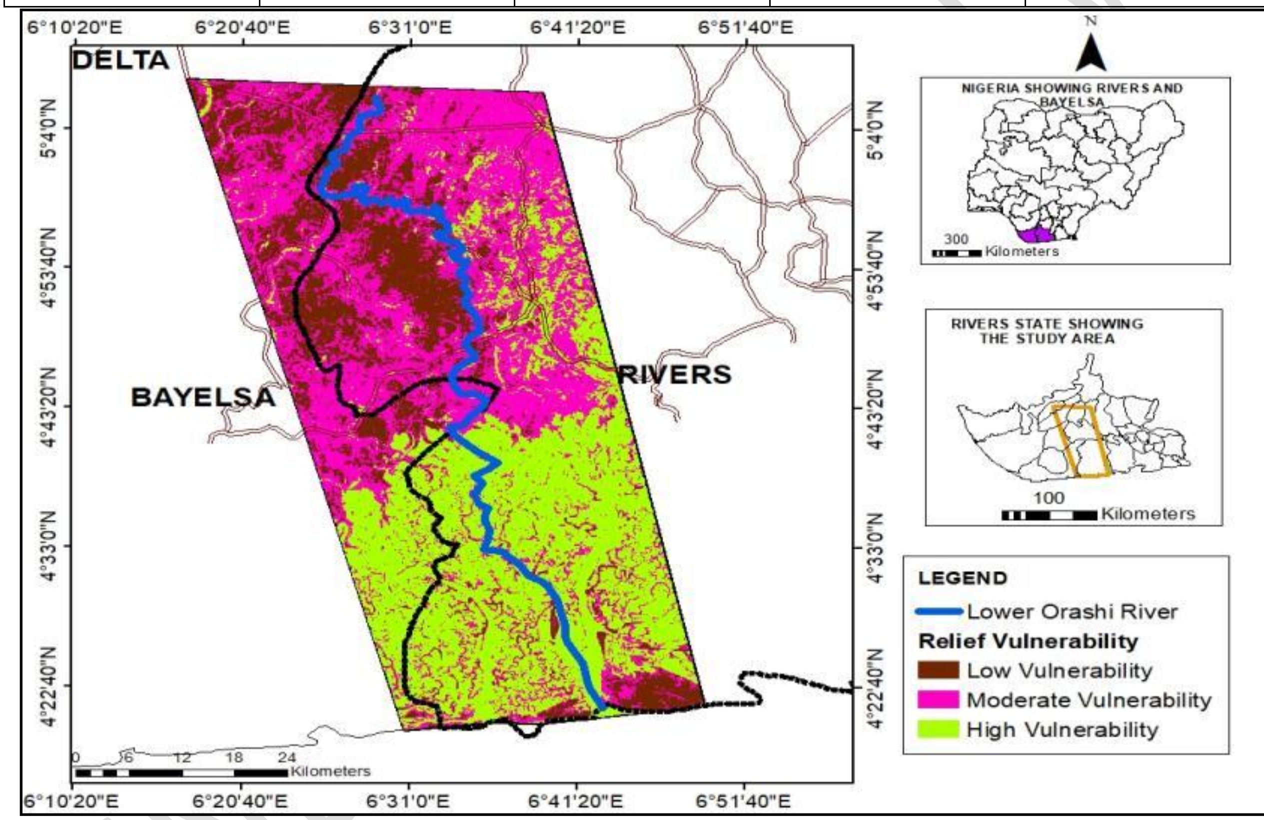

Figure 8: Flood Vulnerability of the Study Area based on Relief

Slope Degree

The analysis concerning the slope in degree is shown in Table 8while the slope in degree vulnerability to flood is shown in Figure 9.It is revealed that 992.3 sq km (30.81%) was being covered by the slope between 0 and 0.63 degree. It is also know in the analysis that slope between 0.64 and 1.37 covered 1193.1 sq km (37.04%), between 1.38 and 2.28 degrees; between 1.38 and 2.28 degrees was 622.88 sq km (19.34%), between 2.29 and 3.56 degrees was 278.98 sq km (8.66%), between 3.57m and 5.52m was 108.54 sq km (3.37%) while those areas between 5.53 and 11.65 degree had 25.06 sq km (0.78%). It is thus seen in the analysis that majority of the entire area fell within 0 and 1.37 slope degreed confirming that the elevation of the study area was a flat topography which usually support the retention of flood because of some deposition activity while makes runoff to be as slow as possible.Considering the flood vulnerability levels based on the slope degree, it is observed that the high vulnerability occupied 67.85%, moderate vulnerability covered 28.00% while low vulnerability from 3.57 to 11.65 degree had 4.15%. This also shows that more areas within the study area are prone to high flood vulnerability based on the slope degree.

Table 8: Slope Degree and its Flood Vulnerability Levels

Slope Degree	Spatial Extent (sq km)	Percentage (%)	Vulnerability Assigned Values	Vulnerability Interpretations
0.0.63	992.5	30.81	3	High Vulnerability
0.64-1.37	1193.1	37.04	3	High Vulnerability
1.38-2.28	622.88	19.34	2	Moderate Vulnerability
2.29-3.56	278.98	8.66	2	Moderate Vulnerability
3.57-5.52	108.54	3.37	1	Low Vulnerability
5.53-11.65	25.06	0.78	1	Low Vulnerability
Total	**3221.06**	**100.00**		

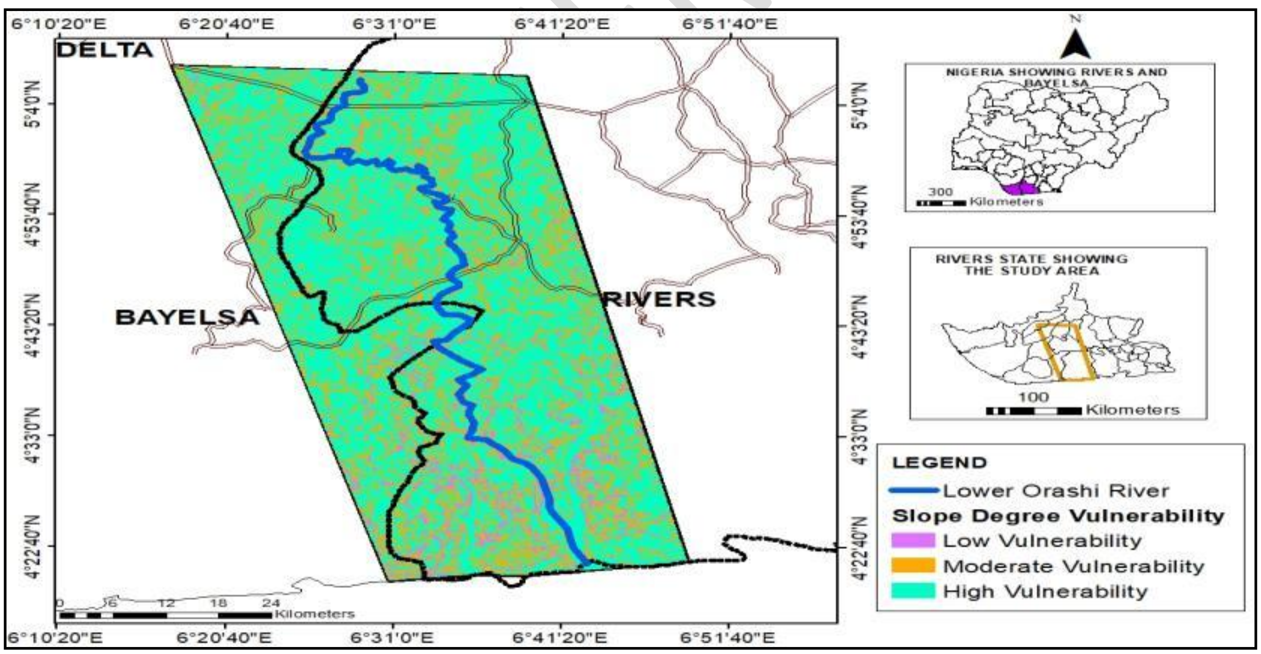

Figure 9: Slope (Degree) Vulnerability to Flood

Slope Percentage Rise

The analysis concerning the slope rise in percent is shown in Table 9, while the slope rise in percent flood is shown in Figure 10. It is revealed that 1115.63 sq km (34.64%) was being covered by the slope between 0 and 1.21 percent. It is also discovered in the analysis that slope percent between 1.22 and 2.50 covered 1151.87 sq km (35.76%), between 2.51 and 4.12 percent was 572.96 sq km (17.79%); between 4.13 and 6.30 percent was 250.96 sq km (7.76%), between 6.31 and 9.78 percent was 105.78 sq km (3.28%), and between 9.79 and 20.62 percent was 23.82sq km (0.74%) while those areas between 5.53 and 11.65 degree had 25.06 sq km (0.78%). It is thus seen in the analysis that majority of the entire area fell within 0 and 2.50 slope percent confirming similar revelation from the slope in degree.Considering the flood vulnerability levels based on the slope degree, it is observed that the high vulnerability occupied 70.40%, moderate vulnerability covered 25.58% while low vulnerability from 6.31 to 20.62 percent had 4.15%. This also shows that more areas within the study area are prone to high flood vulnerability based on the slope percent.

Table 9: Slope Rise (Percent) and its Vulnerability in the Study Area

Slope Percentage Rise (%)	Spatial Extent (sq km)	Percentage (%)	Vulnerability Assigned Values	Vulnerability Interpretations
0-1.21	1115.63	34.64	3	High Vulnerability
1.22-2.50	1151.87	35.76	3	High Vulnerability
2.51-4.12	572.96	17.79	2	Moderate Vulnerability
4.13-6.30	250.96	7.79	2	Moderate Vulnerability
6.31-9.78	105.78	3.28	1	Low Vulnerability
9.79-20.62	23.82	0.74	1	Low Vulnerability
Total	3221.02	100.00		

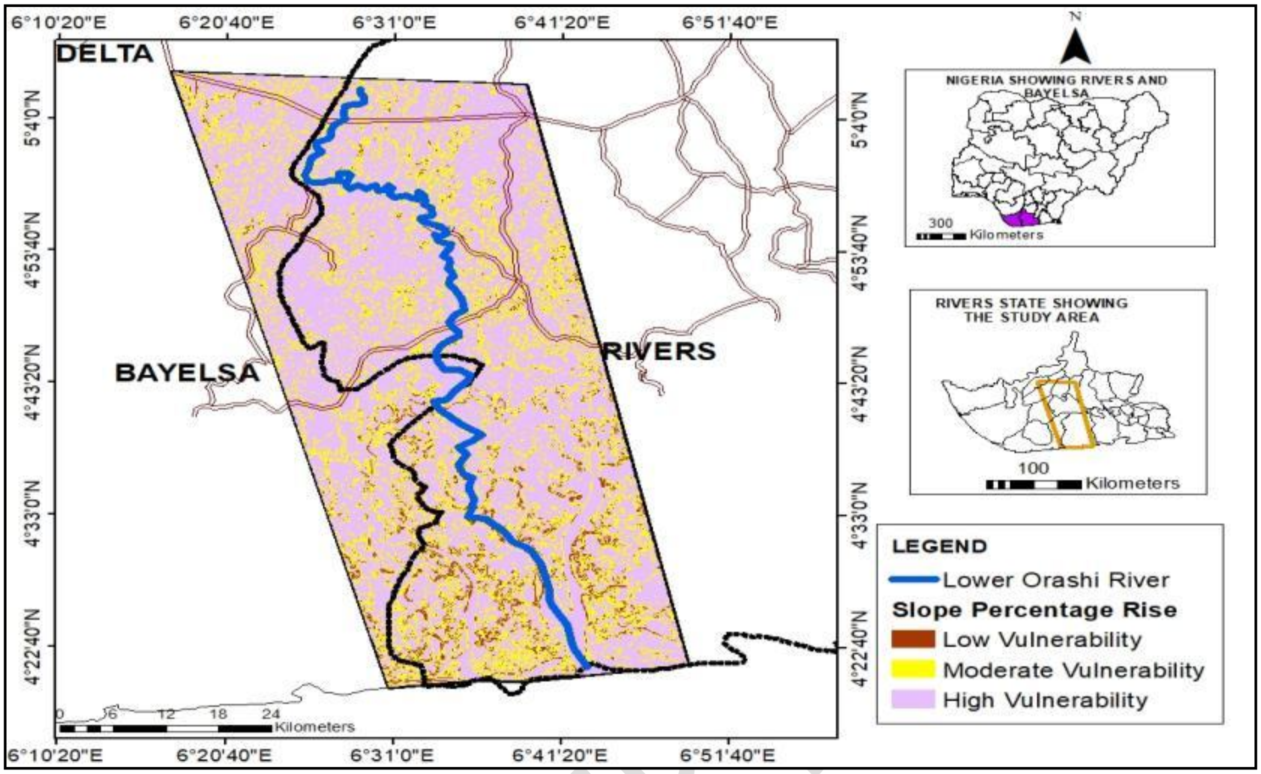

Figure 10: Slope Rise (Percent) Flood Vulnerability

The Stream Power Index (SPI) Flood Vulnerability

It is shown that the flow accumulation and flow direction analysis were used to generate the SPI of Lower Orashi River in Figure 11 while the SPI vulnerability to flood is presented Figure 12.It is revealed that the SPI ranged from -1.41 to 1.82. The SPI of class between -1.41 and -0.18 had 186.81 sq km (6.06%) were of the high flood vulnerability, between -0.17 and 0.10 are the moderate flood vulnerability while between 0.11 and 1.82 recorded 1750.53 sq km (56.77 %). This shows that low SPI dominated the entire study.

Table 10: SPI of the Study Area and its Vulnerability Levels

SPI	Spatial Extent (sq km)	Percentage (%)	Vulnerability Assigned Values	Vulnerability Interpretations
-1.41 - -0.37	34.45	1.12	3	High Vulnerability
-0.36 - -0.18	152.36	4.94	3	High Vulnerability
-0.17 - -0.05	421.99	13.68	2	Moderate Vulnerability
-0.04 – 0.10	724.53	23.49	2	Moderate Vulnerability
0.11 – 0.52	1229.1	39.86	1	Low Vulnerability
0.53 – 1.82	521.43	16.91	1	Low Vulnerability
Total	3083.86	100.00		

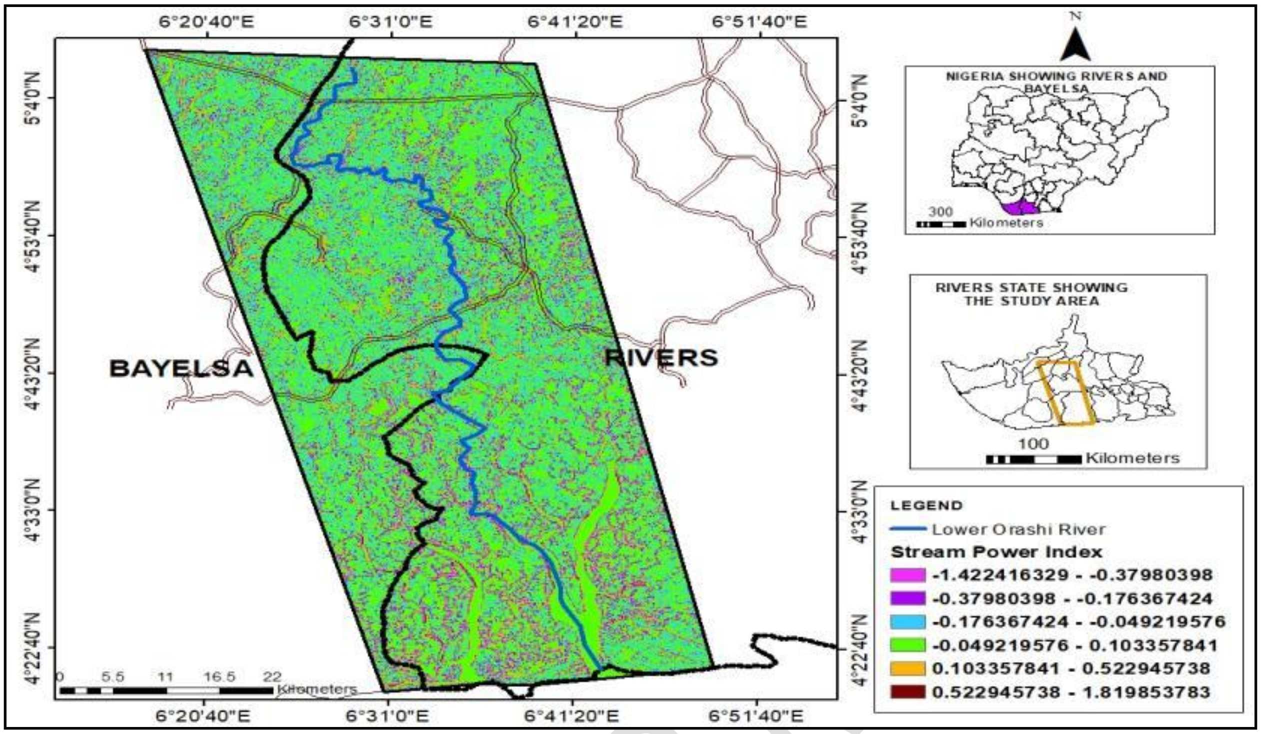

Figure 11: SPI of the Study Area

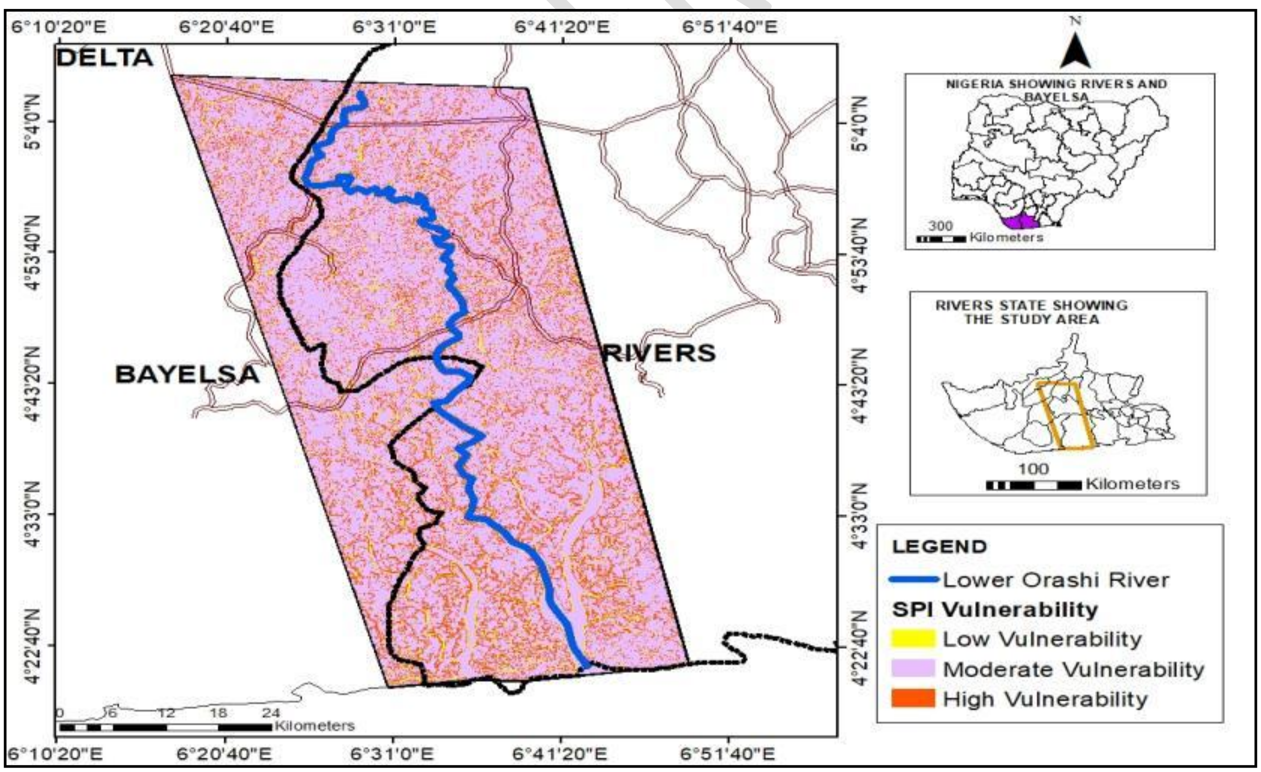

Figure 12: SPI Vulnerability to Flood in the Study Area

Classification the study area into varying flood Vulnerability levels

The flood vulnerability level around Lower OrashiRiver is displayed in Table 11. It is found that the very low flood vulnerability levels covered spatial extent of 244.4 sq km (7.31%), low flood vulnerability covered 901.31 sq km (26.95%), moderate flood vulnerability level covered 1240.18 sq km (37.08%), high flood vulnerability level had 846.47 sq km (25.31%) and very high had 112.11 sq km (3.35%). The analysis is displayed in Figure 13. The high and very high flood vulnerability levels are more occurring in the southern part of the study area which is found around Kula Area.

Table 11: Flood Vulnerability Levels

Flood Vulnerability Levels	Spatial Extent (Sq km)	Percentage (%)
Very Low	244.4	7.31
Low	901.31	26.95
Moderate	1240.18	37.08
High	846.47	25.31
Very High	112.11	3.35
Total	**3344.47**	**100.00**

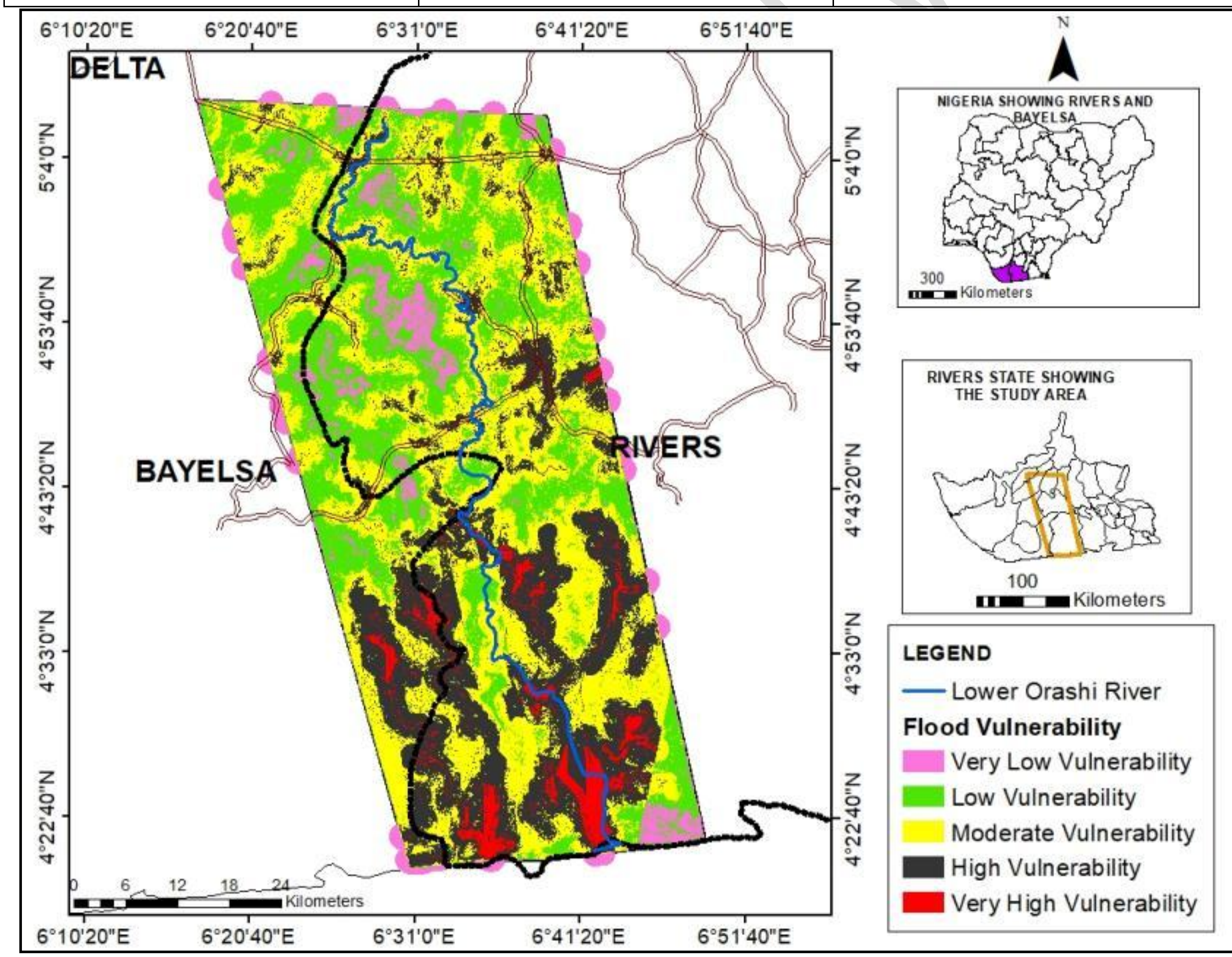

Figure 13: Flood Vulnerability Levels around Lower Orashi River

Discussion of Findings

Findings revealed that more than 65% of the study area was classified to be of minimum of moderate flood vulnerability. This is an indication that majority of the lower Orashi River is prone to flooding if care is not taken and many communities would be vulnerable to both moderate and high flood vulnerability. This is demonstrated in the previous works of [1], [10], [22], [16]and [15]. The flood vulnerability of the lower Orashi River is a true reflection of the entire Niger Delta which is prone to flooding every year. Industry and Energy Operations Division (1995) noted that flooding induced land degradation is a problem throughout the Niger Delta. The construction of upstream dams and subsequent sedimentation of the reservoirs has created very large annual floods that supply little sediment to the delta. Increased flooding and reduced sediment loads, as well as greater population and farming activities in flood prone areas, has intensified the negative impact of flooding. Direct losses from flooding include large areas of valuable land which cannot be cultivated and the destruction of infrastructure and housing. In addition, flooding substantially degrades the health status of both rural and urban communities by increasing the prevalence of water-related diseases.The results of the analysis show that landuse, proximity to drainage channel, soil texture and elevation, SPI, of Lower Orashi River has brought about determining the flood vulnerability levels of the study area. However, it is revealed that built up area is a major component of flood vulnerability under landuse. This is due to the increase in urbanization which usually supports runoff. Thus, built up area is a major landuse with high vulnerability to flood which can cause loss of lives and properties. More than 7700,000 hectares of arable land and built up areas are damaged due to flooding in Nigeria [5]. Recorded damages include destruction of schools, houses built with mud brick and other traditional building materials, bridges, markets and agricultural lands [10]. The progressive increase in the severity of flooding experienced over the past years may be strongly related to increase in urban development that involved the development of swamps and river channels due to increase in population and accommodation demands [3]. In a related development and according to [3], much of the flood disasters in Ethiopia are attributed to rivers that overflow or burst their banks and inundate downstream plain lands. It was understood in [17] highlighted land and physical development problems, gaps in basic hydrological data, design and implementation problems and cultural factors as factors accentuating flood problems in Benin City, Nigeria. It was also established by [25] that the hydro-meteorological changes driven by urbanization, and resulting impacts on extreme rainfall could also be factors that brought about the increase in the flood extent in the built up area. The slope in particular affects the flood vulnerability in the study area.When rain falls on natural slopes covered by healthy vegetation, the plants and soil absorb and slow down some of this water. However, development on steep slopes often disrupts these natural functions and results in more runoff, faster runoff, and less protection for the soil. Concentrated high energy flow causes erosion, washouts, and landslides. Increased peak flows cause flood damage to homes and property.

Conclusion and Recommendations

The study can be concluded that the combinations of the elevation, rainfall, SPI, soil texture, landuse/land cover and proximity to active channels have led to varying flood vulnerability levels in the lower Orashi River and that more than 65% of the entire lower Orashi River are highly and moderately vulnerable to flood. It is therefore recommended among others that periodic flood assessment should be encouraged in the study area and baseline data on flood levels for flash flood or elongated flood should be taken and documented at all times

References

1.Amangabara, G. T. and Obenade M. (2015). Flood vulnerability Assessment of Niger Delta States Relative to 2012 Flood Disaster in Nigeria. American Journal of Environmental Protection, vol. 3, no. 3 (2015): 76-83. doi: 10.12691/env-3-3-3

2. Ayeni, B., Adagbasa, E., and Samuel, K.J. (2014). A Geospatial Analysis of Flood Risks and Vulnerability in Ogun-Osun River Basin, Nigeria. www.researchgate.net/publication/280087295Retrieved 2021-05-13.

3. Bishaw, (2012). *Application of GIS and remote sensing techniques for flood hazard and risk assessment*. Proceeding of the Berlin Conference on the Human Dimensions of Global Environmental Change.

4.Cardona, O. (2012). *Determinants of Risk : Exposure and Vulnerability Coordinating Lead Authors : Lead Authors : Review Editors : Contributing. Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation.* A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC), 65–108.

5.Chiadikobi, K. C., Omoborow, A. O., Chiaghanam, O. I., Opatola, A. O., Oyebani, O. (2011). Flood risk assessment of Port Harcourt, Rivers State, Nigeria. *Advances in applied science research* 2(6), 287 -298

6.Fabiyi, J. S. (2011). Effects of wood species on durability and chemical changes of fungal decayed wood plastic composites. *Composites Part A: Applied Science and Manufacturing*, *42*(5), 501-510.

7.Geographical Alliance of Iowa (2010). *Teaching geography & standards*. https://gai.uni.edu/ teaching- geography-standards.

8.Grant K. (1988). *Terrain evaluation systems. In: General Geology. Encyclopedia of Earth Science*. Springer, Boston, MA.

9.Happy, O.N., & Shuaib, M.E. (2014), Flood vulnerability assessment and disaster risk in Kubwa, FCT, Nigeria. *American Journal of Environmental Science and Engineering, 1*(2), 55-66.

10.Mmom, P.C. and Ayakpo A. (2014). Spatial analysis of flood vulnerability levels in Sagbama Local Government Area using geographic information systems (GIS). Int. J. Res. Environ. Stud (2014): 1-8.

11.Najibi, N., & Devineni, N. (2017). Recent trends in the frequency and duration of global floods. *Earth Systems Dynamics, 9*(2), 757–783.

12.National Geographic. (2018). *Floods*. https://www.nationalgeographic.com/ environment/ natural-disasters/floods/

13.Njoku, C.G., Effiong, J., & Ayara, N.N.A. (2020). A geospatial expose of flood-risk and vulnerable areas in Nigeria. *International Journal of Applied Geospatial Research, 11*(3), 1-24

14.Nkwunonwo, U.C., Whitworth, M., & Baily, B. (2015). Geography and natural disasters: Flooding and flood risk reduction in Nigeria: Cardinal gaps. *Geography and Natural resources*, *5*(5), 11-19.

15.Nwankwoala H O & Jibril T (2019). Flood height measurement and analysis in parts of Obio/Akpor Local Government Area, Port Harcourt Metropolis, Nigeria. *Engineering Management Research, 8*(2), 1-10.

16.Obenade M., Famurewa A.J. & Gumus S. (2020). Flood vulnerability and risk assessment: A case study of Yenagoa and its environs, Bayelsa State, Nigeria. *International Journal of Scientific & Engineering Research*, *11*(9), 592-599

17.Odemerho, (2004). Spatial analysis of flood prone areas in Ilaje local government area, Ondo state Nigeria. *Journal of applied sciences and technology* 6(3), 76-85

18.Okoye, C. B., &Ojeh, V. N. (2015). Mapping of flood prone areas in Surulere, Lagos, Nigeria: A GIS approach. *Journal of Geographic Information System*, *7*(02), 158.

19.Peduzzi, P., Dao, H., Herold, C., & Mouton, F. (2010). Assessing global exposure and vulnerability towards natural hazards: The disaster risk index. *Natural Hazards and Earth System Sciences, 9*(4), 1149–1159

20.Praveen, B., & Sharma, P. (2019). A review of literature on climate change and its impacts on agriculture productivity. *Journal of Public Affairs*, *19*(4), e1960.

21.Shroder, J.F. (2014). *Terrain analysis*. www.sciencedirect.com/topics/earth-and-planetary-sciences/terrain-.

22.Wizor, C. H., & Week, D. A. (2014). Geospatial mapping and analysis of the 2012 Nigeria Flood disaster extent in Yenagoa city, Bayelsa State, Nigeria. *Journal of Environment and Earth Science*, *4*(10), 64-77.

23.World Health Organization (WHO) (2014). *Floods*: climate change and adaptation strategies for human health. Report on a W.H.O meeting, London, United Kingdom.

24.Yusuf, O. M., & Oladapo, A. I. (2017). Morphometric analysis of Asa and Oyun River Basins, North Central Nigeria using Geographical Information System. *American Journal of Civil Engineering*, *5*(6), 379-393.

25.Zhao, W., Huang, W., Yin, M., Huang, P., Ding, Y., Ni, X. & Cai, M. (2020). Tributary inflows enhance the microplastic load in the estuary: a case from the Qiantang River. *Marine Pollution Bulletin*, *156*, 111152.