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Research Paper

Flood Vulnerability Assessment of Communities in the Flood Prone Areas of Bayelsa State, Nigeria

Berezi O. K.[1], Obafemi A. A.[1,2,3] and Nwankwoala H. O.[1,4]*

*Corresponding Author: **Nwankwoala H. O.** ✉ nwankwoala_ho@yahoo.com

The study examined the flood vulnerability levels of communities in Bayelsa State, Nigeria with a view to employing Analytical Hierarchical Process (AHP) techniques which makes use of GIS-based overlay analysis to determine spatial flood vulnerability levels. The study considered the landuse, elevation, soil texture and proximity to active river channels as factors determining flood vulnerability. The components of these factors were reclassified as low, moderate and high vulnerabilities with assigned numbers of 1, 2 and 3 respectively using the ranking method. All the maps were overlaid using the UNION module which made it possible to detect different flood vulnerability levels. The analysis showed that the areas that have low vulnerability to flood were 2020.40 km^2 (12.9%) of the entire area. The moderate vulnerability areas covered a spatial extent of 9342.04 km^2 (59.8%), while high vulnerability areas covered 4248.95 km^2 (27.3%) in the overlay of communities on the flood vulnerability levels of Bayelsa State. Findings revealed that 43 (14.98%) communities including Agbalamabugokiri, Agberi, Akassa, Bisagbene, Bolougbene, Bwama, Orukiri, Otokolopiri, Spiffs Town, Tomkiri and Twon had low flood vulnerability levels. The communities with moderate vulnerability feature were about 287 (73.78%) which included Abagbene, Abulabiri Agudama, Aziama, Brass, Burukiri, Ebelibiri, Ekeremor, Fangbe, Gbaran, Karama, Nembe, Ogboinbiri, Ogbomama, Opuama, Tombia, and Uruama. However, 59 (15.17%) of the entire communities were highly vulnerable to flood in Bayelsa State. Among these communities included Abolikiri, Akaba, Amarara, Biogbolo, Ekeki, Okokokiri, Okpokiri, Okpoma, Polaku, Swali, Tuluama, Yenagoa and Yenezue-Epie. The study concluded that higher proportion parts of Bayelsa State are vulnerable to flood and it is recommended that regular flood assessment should be encouraged in Bayelsa State; and the communities with high and moderate vulnerability to flood should be provided with adequate preparedness in case of any flood disaster.

Keywords: Flood vulnerability, GIS, Land use, soil texture, Elevation, River channels, Bayelsa State

[1] Institute of Natural Resources, Environment and Sustainable Development, University of Port Harcourt, Port Harcourt, Nigeria.
[2] Department of Geography and Environmental Management, University of Port Harcourt, Port Harcourt Nigeria.
[3] Centre for Disaster Risk and Developmental Studies, University of Port Harcourt, Port Harcourt, Nigeria.
[4] Department of Geology, University of Port Harcourt, Port Harcourt, Nigeria.

Introduction

Flooding is one of the most devastating, frequent and widespread of all environmental hazards and of various types and magnitudes (Wizor and Week, 2014; Nwankwoala and Jibril, 2019). Flood is an inevitable natural phenomenon occurring from time to time in all rivers and natural drainage systems, which not only damages the lives, natural resources and environment, but also causes loss of economy and health year after year (Thilagavathi, *et al.,* 2011). Floods can be defined as a large quantity of water covering a dry land. It occurs when water temporarily covers an area that it usually does not due to excess rainfalls than the soil and vegetation can absorb. The excess water runs off the land in greater quantities than rivers, streams, ponds and wetlands can contain. Heavy rains of such nature periodically cause rivers to overflow their banks, spilling onto the surrounding floodplains. Flood is a naturally occurring event that is dependent not only on rainfall amounts, but also on the topography of the area, and antecedent moisture conditions. It has displaced people, claimed lives and destroyed properties.

Floods are generally classified as fluvial (Riverine), pluvial (Ponding), flash, coastal and urban floods. Fluvial floods are as a result of water from rivers when the rivers' banks overflow usually as a result of excessive rainfall. Pluvial floods on the hand, occurs when there is excessive rainfall such that the natural drainage systems are saturated and unable to discharge water. Flash floods occur when water rises suddenly to unsafe levels in a rapid manner with little or no advance warning. It usually results from intense rainfall over a relatively small area. Urban floods occur as a result of land development without proper drainage mostly in urban areas. Permeable soil layers are been replaced by impermeable paved surfaces, through which water cannot infiltrate leading to generation of greater runoffs, causing rivers, roadways and parks to flood. Simply, coastal flood is when the coast (i.e. a water touching land strip) is flooded by the sea. The sea can overflow or overtop flood defenses such as sea walls, perhaps due to a heavy storm (storm surge), a high tide, a tsunami or a combination thereof. Bayelsa State is seen as one of the most susceptible states in Nigeria to flooding due to its location in the heart of the Niger Delta. Flood arising from annual coastal rising waters has been plaguing most communities in the state and the Niger Delta even before the era of climate change awareness. Recent flood disasters in Bayelsa State and Nigeria at large, has claimed many lives and properties, and threatened the ecological biodiversity. Bayelsa State annually experiences flood occasioned by climate change that triggers devastating losses in human lives, economic assets, school attendance with multiplier consequences for the education system (Allen, 2015).

The 2012 floods experienced in the Niger Delta states occasioned by the climate change pandemic had serious consequences on Bayelsa state especially the educational sector where schools were closed down. It is described as the most severe and devastating flood disaster in the history of Nigeria in which 2.3 million people were displaced, over 363 persons were killed and about 597,476 houses were destroyed (Wills, 2014). The historic flood as posited by Akpokodje (2012) was caused by several factors which includes: Unusual rainfall associated with extreme climatic conditions caused by climate change and global warming, improper land use and development of natural water ways, blockage of drains and street inlets and the release of water from the Lagdo Dam in Cameroun and Kainji, Jebba and Shiroro on River Niger. However, the root cause of the 2012 Great floods in Nigeria is attributed to the flooding of Rivers Niger, Benue and their tributaries arising partly from some of the runoff generated as far away as the foothills of the Futa Jalon Mountains in the Republic of Guinea; which end up in the flood plains of the Niger Delta.

The Niger Delta is the main coastal flood plain through which the Niger-Benue river system discharges into the Atlantic Ocean. According to Fubara (2012), the negative impacts of the 2012 flood is worse than the 60 years of oil pollution in the Niger Delta. The reason is that all the effluent discharges, the waste pits, the acidified waters etc have been washed into the rivers and other water bodies and since Bayelsa State provides the corridor for the numerous distributaries of Niger-Benue River system to discharge into the sea; the state has a very high vulnerability index not only to flood hazards arising from the Niger-Benue River system but also from rising sea levels occasioned by climate change. Flood Vulnerability Index (FVI) as considered in the study of floods is the extent of harm, which can be expected under certain conditions of exposure, susceptibility and resilience (UNESCO IHE, 2013). In line with this Nyananyo (2007) posited that no measure will avail the problems of flooding in the state without construction of buffer dams, preventing siltation of the Rivers, creeks and other waterways by dredging the water bodies and clearing the drains in the urban towns of debris. It was suggested by Nyananyo (2007) that strategic approaches should be adopted especially that of building of buffer dams before and further down the bifurcation zone of Rivers Niger into Forcados and Nun probably at Asamabiri, Agbere/Odoni and lower down the River Nun near Odi town. Prevention is the best option to check flooding in the state.

The vulnerability of a place on earth surface to flood is a function of the region's exposure to the hazard, (natural event) and the anthropogenic activities carried out within the catchment area which impedes the free flow of water. In the last 20 years, the notion of vulnerability has changed. Vulnerability is considered in the study of Flood Vulnerability Index (FVI) as the event of harm, which can be expected under certain conditions of exposure, susceptibility and resilience (UNESCO IHE, 2013). This is so because human population worldwide is vulnerable to natural disasters and in recent years the impacts of floods have gained importance because of the increasing amount of people who are exposed to its adverse effects. Generally, the purpose of vulnerability studies is to recognize correct actions that can be taken to reduce vulnerability before the possible harm is realized by building community resilience through adaptation and mitigation measures. Therefore, identifying areas with high flood vulnerability may guide decision making process towards a better way of dealing with flood societies. The FVI is a powerful tool for achieving this purpose.

Remote sensing and GIS are geo-information technologies that can be used to assess flood vulnerability and produce flood risk maps which are essential tools to identify flood vulnerability areas (Jeb and Aggarwal, 2008). According to Demessie (2007) and Manandhar (2010), GIS has been used in developing flood risk maps that show vulnerability to flooding in different places around the world. Unfortunately this detailed knowledge is always lacking in the developing world like Nigeria (Ishaya *et al*., 2009). Although, few studies on flood have been carried out in some local government areas in Bayelsa State like Sagbama LGA (Mmom and Akpi, 2014); Yenagoa LGA (Wizor and Week, 2014) and Kolokuma/Opokuma LGA (Berezi et al, 2015); there is no detailed study of flood on the entire Bayelsa State. It is against this background, the study investigated the community vulnerability to flood risk in Bayelsa State, Nigeria.

Materials and Methods

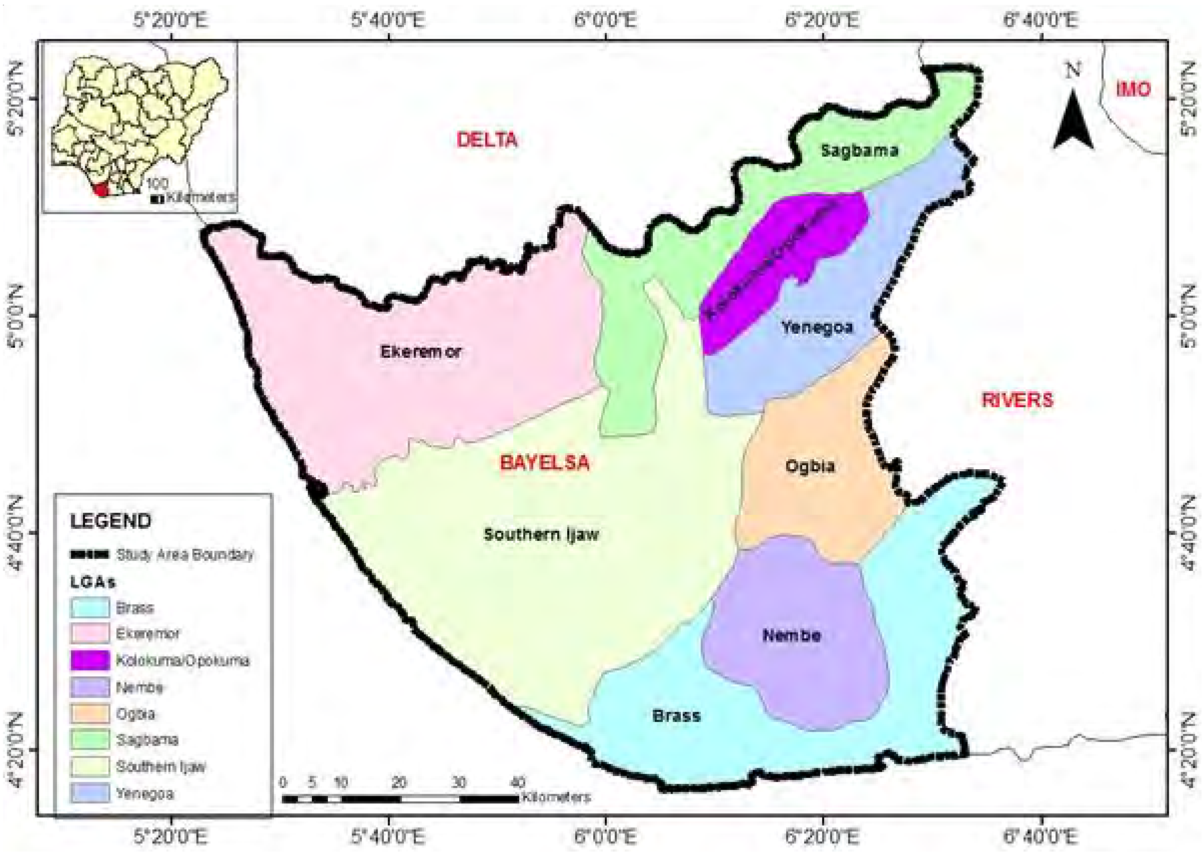
The study area adopted for this paper was the entire Bayelsa State. Bayelsa State is in the Central Niger Delta and situated between the Niger and the lower Niger floodplain of the Niger Delta Region. It falls within the geographical location of latitude 4^o 20'N and 5^o 20'N and longitudes 5^o 20'E and 6^o 40'E (Figure 1). The state shares boundary with Delta on the North, Rivers on the East and is bounded on the West and South by the Atlantic Ocean. It has a population of about 1.7 million people based on the Nigerian 2006 census [National Population Commission, 2016]. The study area has a tropical climate with two distinct seasons, wet (April-October) and dry (November-March). It also experience two distinctive prevailing winds. These are the dry and dusty laden tropical continental air mass and the moist tropical maritime air mass. The tropical continental air mass is otherwise known as Harmattan wind (Osuiwu and Ologunorisa, 1999). It is a dry cold wind, embedded in the North-East trade wind that blows over the area from December to February (dry season). Alagoa (2013) posited that the mean annual rainfall ranges from 2,000 to 4,000mm and spreads over 8 to 10months of the year between the months of March and November, this coincides with the wet season. Bayelsa State is located within the lower delta plain believed to have been formed during the Holocene of the Quaternary period by the accumulation of sedimentary deposits. The major soil types in the state are young, shallow, poorly drained soils and acid sulphate soils. Youdiowei and Nwankwoala (2011) posited that the major soil types of the study area are light to dark grey; fine sand to silty clay. Like any other area in the Niger Delta, the vegetation in Bayelsa State is composed of mangrove forests, freshwater swamp and lowland rain forests. Commercial timber species are also found in the area (Akpokodje, 1987). The main occupation of the people includes farming and fishing.

This study employed the use of Landuse map of Bayelsa State acquired from the Landsat Imagery of 30m x 30m and the drainage network, road network, and communities location extracted from the topographic map of 1: 100,000 scale of the study area; and soil map derived from the FAO website. The secondary data included the population data of 2006 of the communities from Bayelsa State obtained from National Population Commission (NPC, 2006). Topographic map was obtained from Surveyor General's office, Ministry of Lands and Survey, Bayelsa State.

Geo-Processing and Map Generation

The bands of the landsat satellite imageries of Bayelsa State of path 089 and row 056; and path 089 and row 057 were combined to have single-band imagery for each of the scenes. Thereafter, the scenes merged together using mosaic process together for further analysis. The shapefile of Bayelsa State was used to clip the mosaic imagery to have a definite boundary of the study area. However, topographical map was geo-referenced to world coordinate system (WGS 84) in ArcGIS 10.5 from where the

Figure 1: Bayelsa State showing the LGAs



Source: Bayelsa State Ministry of Land and Survey, 2018

communities (Figure 2) and river networks were obtained while the SRTM imagery was used to determine DEM and thereafter the slope of the area (Figure 3). The names of the selected communities are then automatically labelled and alphabetically arranged through the label module of the ArcGIS software. The soil map in Figure 4 was generated from the World Soil Map created by FAO/UNESCO (1973). The soil map supplied information on the soil dominant composition, the textural class (1=coarse, 2=medium, 3=fine); and slope class of the soil association (a=level to undulating, b=rolling to hilly, c=steeply dissected to mountainous). From the imagery, landuse map of the study area was acquired while drainage network, road network and communities were derived from the topographical map. Soil texture map of Bayelsa State was also geo-referenced to WGS 84. The landuse/land cover map was generated from the satellite imageries using MAXLIKE (Maximum Likelihood Algorithm) module Supervised classification technique. The area in square kilometre of each landuse type was calculated. The landuse identified were thick vegetation, sparse vegetation, developing area, built up area, and water body. The drainage network which determines the proximity to active river channels and communities were digitized and captured from the topographical map as vector data. The elevation map was derived from the SRTM elevation data of 30km grids after the shapefile boundary of Bayelsa State has been used to clip the raster data.

Flood Factors Reclassification and Vulnerability Ranking

This study made use of ranking methods of the vulnerability factors which is embedded in Analytical Hierarchy Process (AHP) proposed by Saaty (1980). AHP is a multi-criteria decision making technique, which provides a systematic approach for assessing and integrating the impacts of various factors, involving several levels of dependent or independent, qualitative as well as quantitative information (Bapalu and Sinha, 2006) Ranking method was adopted because the criterion weights are usually determined in the consultation process with choice or decision makers which resulted in ratio value assigned to every criterion map (Lawal *et al*., 2011). In ranking method, every criterion under consideration is ranked in the order of the decision maker's preference. Therefore, the landuse, proximity to river channels (drainage), elevation and soil texture maps were reclassified into high vulnerability, moderate vulnerability, low vulnerability and no vulnerability. In terms of landuse map, the thick vegetation was reclassified to low vulnerability, developing area and sparse vegetation to moderate vulnerability while built up area and water body as high vulnerability. In terms of drainage network, the communities were rated based on their proximity to the Nun River and its tributaries in the study area. Buffering method was used whereby zones of influence were generated as rings of 500 meters, 1000 meters and 1500 meters from the rivers. The ring of 500m was regarded as high vulnerability, 1000m as moderate vulnerability and 1500m as low vulnerability. The elevation map was also reclassified as follows 7.0m-17.8m to high vulnerability, 17.9m-22.2m to moderate vulnerability and above 22.2m to low vulnerability. The soil types identified included sandy, sandy clay, clay, clayey loam, and sandy loam. Soil strength map was determined using the soil texture and infiltration capability of soil in Bayelsa State (Duncan and Wright, 2005). The soil types identified included sandy, sandy clay, clay, clayey loam, and sandy loam and they were assigned values based on their strength to allow infiltration and run off.

All the vulnerability levels were assigned values 3, 2, 1, that is, from high vulnerability, moderate vulnerability and low vulnerability respectfully. Using these values, the landuse vulnerability map, drainage network vulnerability map, soil texture vulnerability and elevation vulnerability map were overlaid with the use of UNION MODULE. Reclassification method was also applied to have very high vulnerability, high vulnerability, moderate vulnerability, low vulnerability and very low vulnerability. The output of this map was regarded as the flood vulnerability map of Bayelsa State considering the landuse, proximity to river channels (drainage network), elevation and soil texture maps of the area. Spatial query was used to determine the vulnerability levels that each community fell into and also used to determine the spatial extent of each vulnerability level. Descriptive and inferential statistics were used in this study to explain the percentage of the spatial coverage of the highly, moderately and lowly vulnerable communities in Bayelsa State. The results of the classifications and re-classifications carried out in each of the landuse/

land cover, drainage network buffer, soil texture and elevations were also explained using descriptive statistics. Inferential statistics was employed for hypothesis testing.

Figure 2: Communities in Bayelsa State

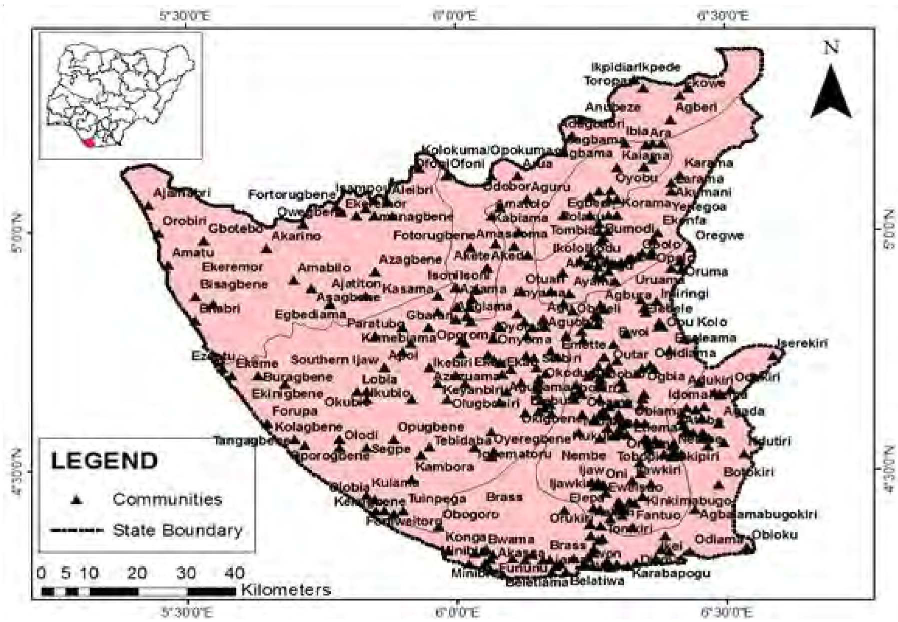


Figure 3: Digital Elevation Model of Bayelsa State

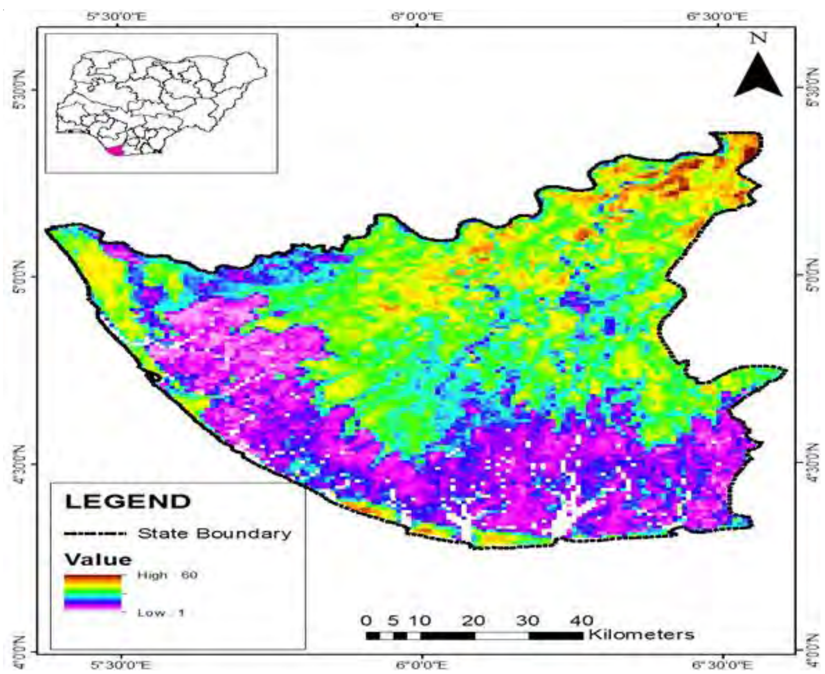


Figure 4: Soil Types of Bayelsa State

Results and Discussion

Landuse Map Vulnerability

The landuse map vulnerability to flood was determined according to the vulnerability levels assigned to each landuse identified in the study area. Table 1, Figure 5 and Figure 6 explain the types of landuse discovered and the spatial extent of each of them. The fresh water swampy forest/farmland had the highest spatial extent (3291.69 km^2), followed by mangrove having 2701.25 km^2. The analysis also revealed that riparian vegetation recorded 1245.20 km^2 while the built up area recorded the 1633.27 km^2 and water bodies had 496.33 km^2. The analysis further showed that the spatial extent of the area for low flood vulnerability covered 35.1%, moderate flood vulnerability was 42.1% while high flood vulnerability was 19.7% (Table 1).

Table 1: Landuse / Landcover Vulnerability Levels to Flood

S. No.	Landuse	Spatial Extent (Km^2)	Percentage (%)	Vulnerability Assigned Values	Vulnerability Levels
1	Water body	496.33	5.3	3	High Vulnerability
2	Riparian Vegetation	1245.20	13.3	2	Moderate Vulnerability
3	Mangrove	2701.25	28.8	2	Moderate Vulnerability
4	Freshwater Swamp/Farmland	3291.69	35.1	1	Low Vulnerability
5	Built Up Area	1633.27	17.4	3	High Vulnerability
	Total	**9367.74**	**100.0**		

Figure 5: Landuse / Landcover of Bayelsa State

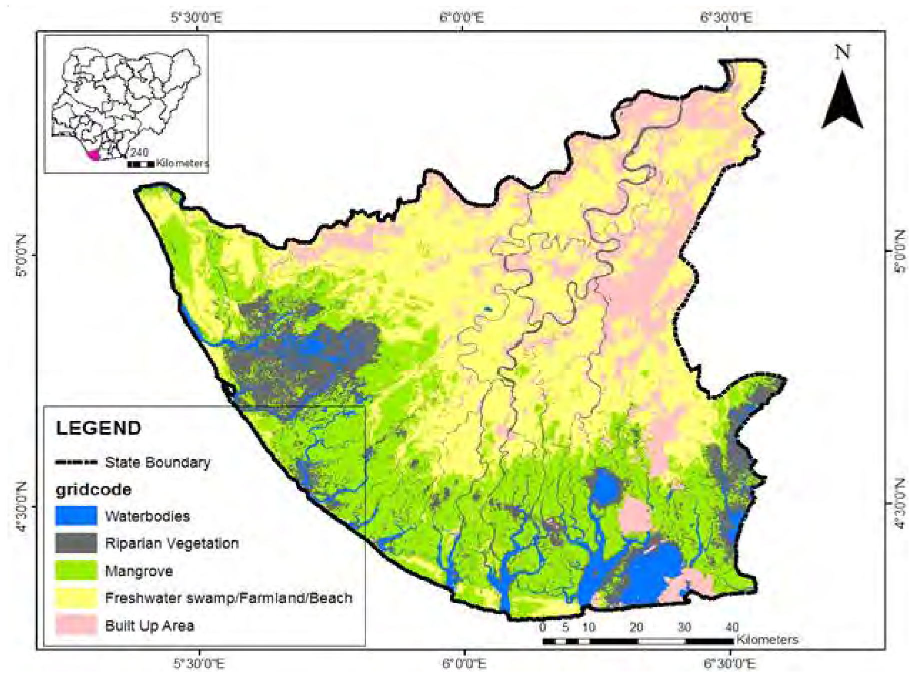
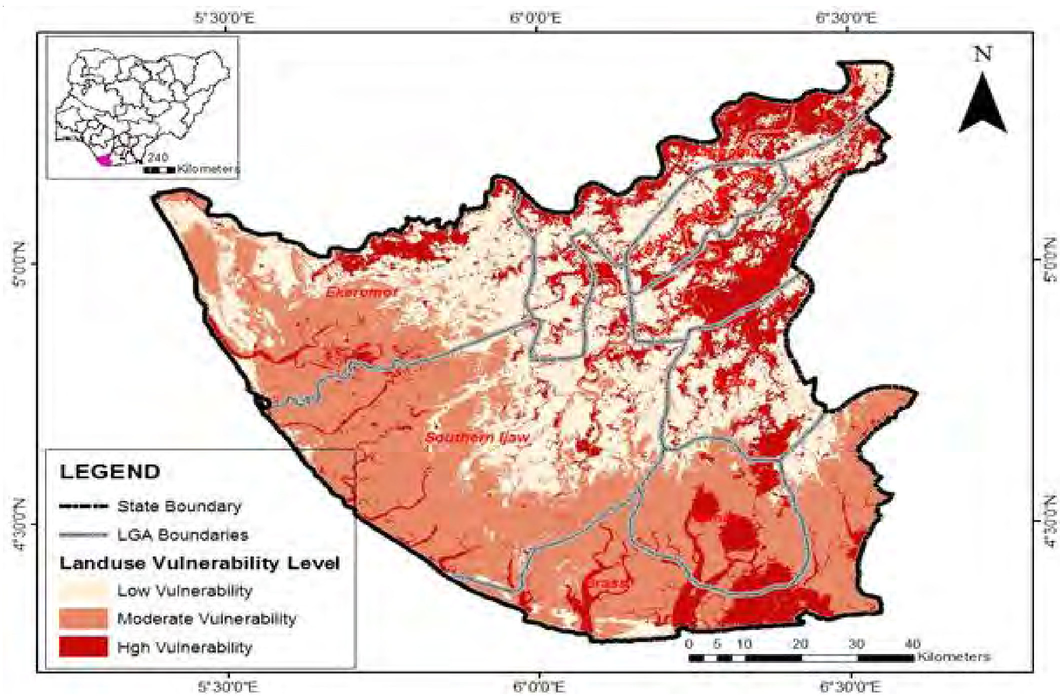


Figure 6: Landuse / Land cover vulnerability map to Flood in Bayelsa State



Proximity to River Channel (Drainage) Vulnerability Map

Table 2 and Figures 7 and 8 describe the drainage network and drainage vulnerability maps of Bayelsa State respectively. The results show that the buffer of 500m from the rivers i.e. high flood vulnerability level based on the proximity to active river channel covered a spatial extent of 0.11 km^2, the buffer of 1000m covered 0.223 km^2 while the buffer of 1500m covered a spatial extent of 0.336 km^2.

Table 2: Proximity to Active River Channel

S. No.	Drainage Buffer (m)	Spatial Extent (m^2)	Percentage (%)	Vulnerability Assigned Values	Vulnerability Levels
1	500	0.11	16.4	3	High Vulnerability
2	1000	0.223	33.3	2	Moderate Vulnerability
3	1500	0.336	50.2	1	Low Vulnerability
	Total	**0.669**	**100.0**		

Figure 7: Drainage Pattern of Bayelsa State

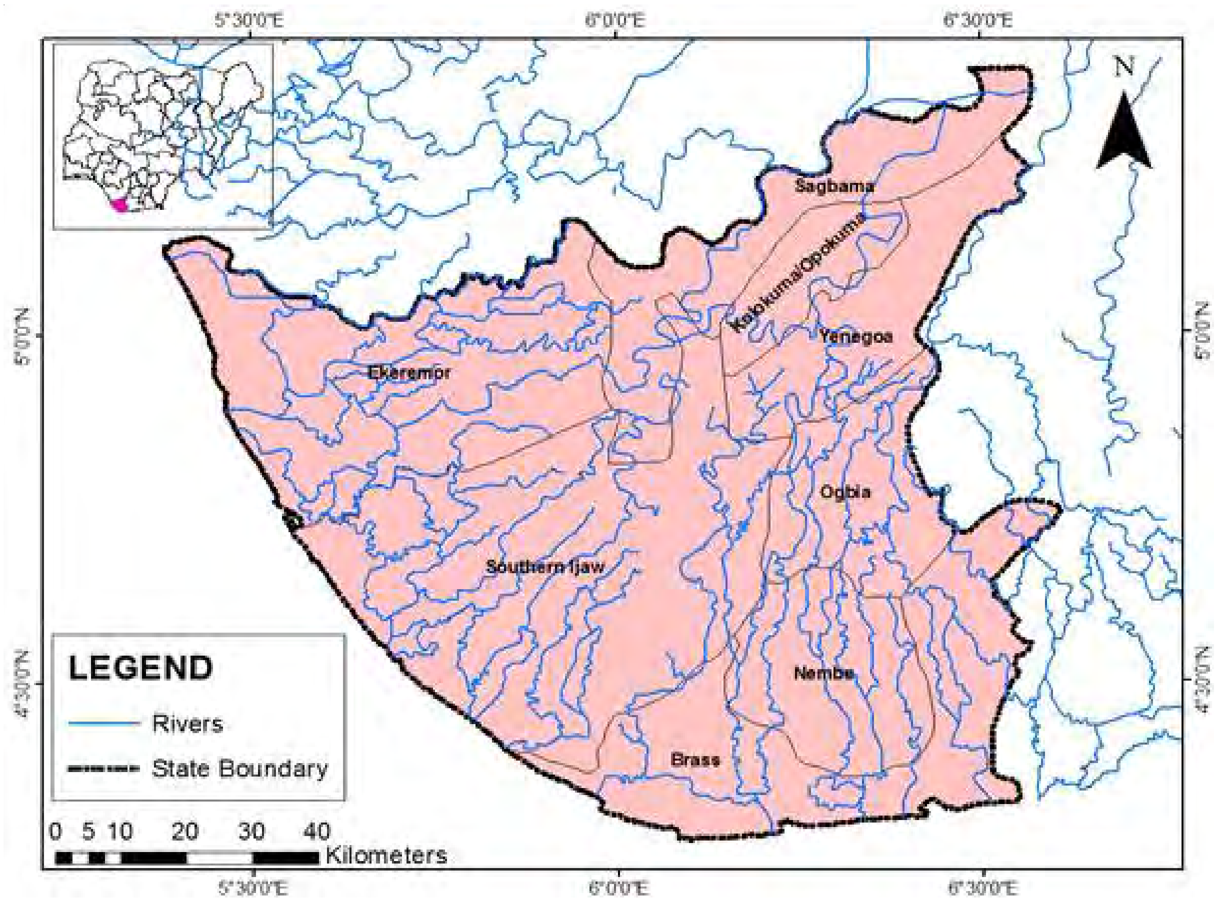
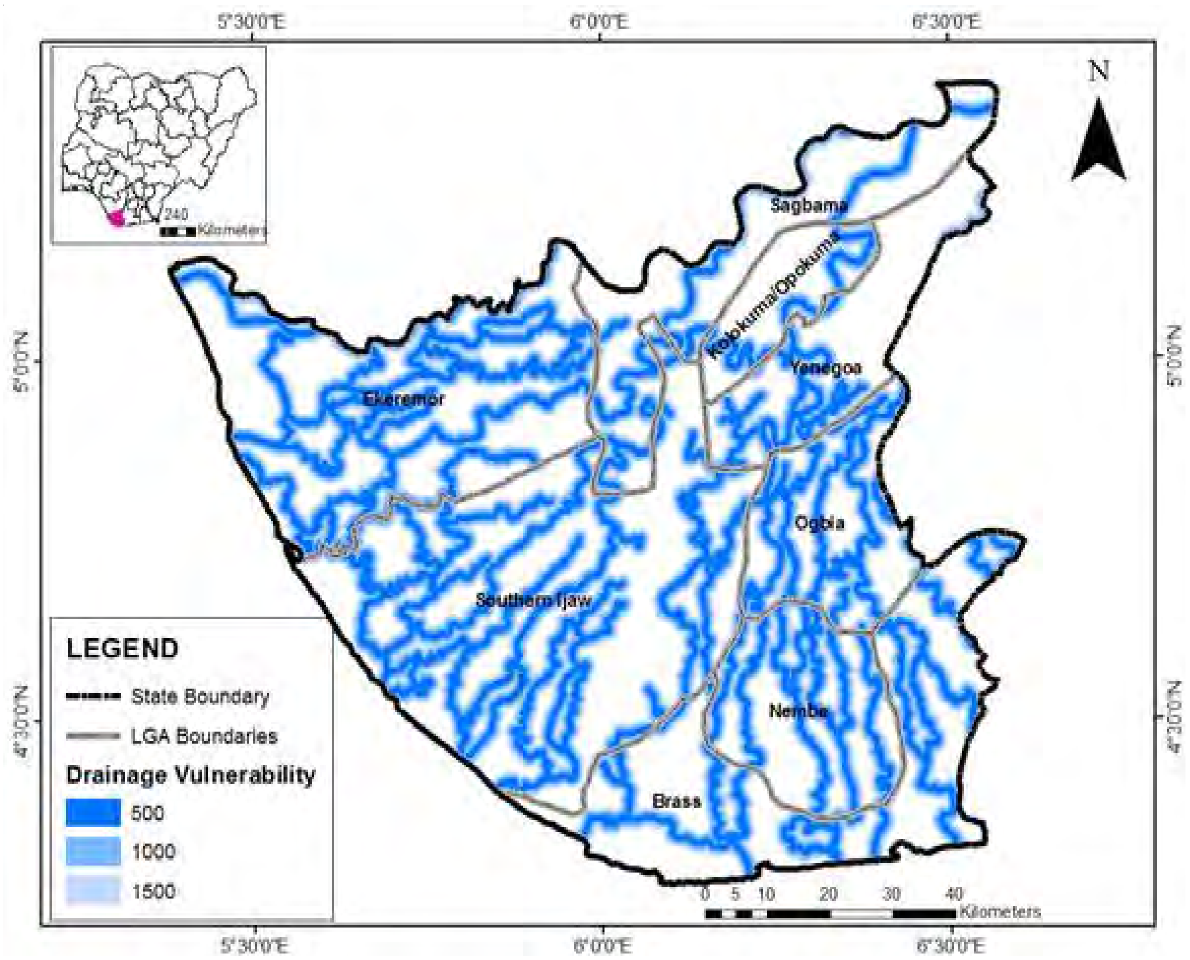


Figure 8: Buffering of Active River Channel of Bayelsa State



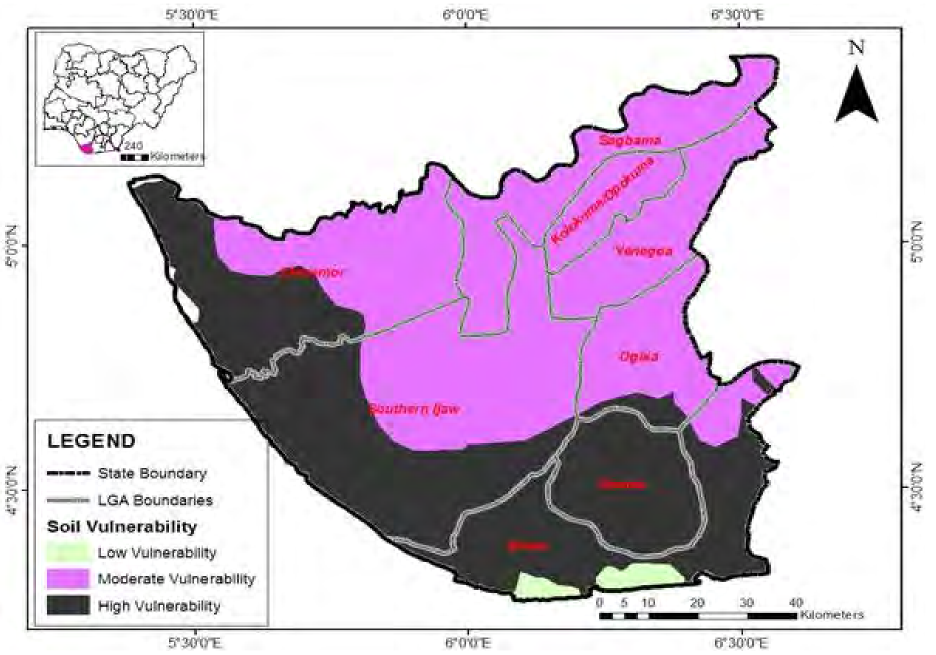
Soil Texture Vulnerability Map

Table 3 and Figures 9 describe the soil texture vulnerability to flood of Bayelsa State. The analysis showed that the medium and fine texture covered 50504.4 km^2 while fine texture covered 4147.0 km^2 and coarse covered 136.1 km^2. This shows that 54.1%, 44.4% and 1.5% was for moderate vulnerable, high vulnerable and low vulnerable respectively.

Table 3: Soil Texture Vulnerability of Bayelsa State

S. No.	Soil texture	Spatial Extent (Km^2)	Percentage (%)	Vulnerability Assigned Values	Vulnerability Levels
1	Medium and Fine	5054.4	54.1	2	Moderate Vulnerability
2	Fine	4147.0	44.4	3	High Vulnerability
3	Coarse	136.1	1.5	1	Low Vulnerability
	Total	9337.5	100.0		

Figure 9: Soil Texture Flood Vulnerability Map of Bayelsa State



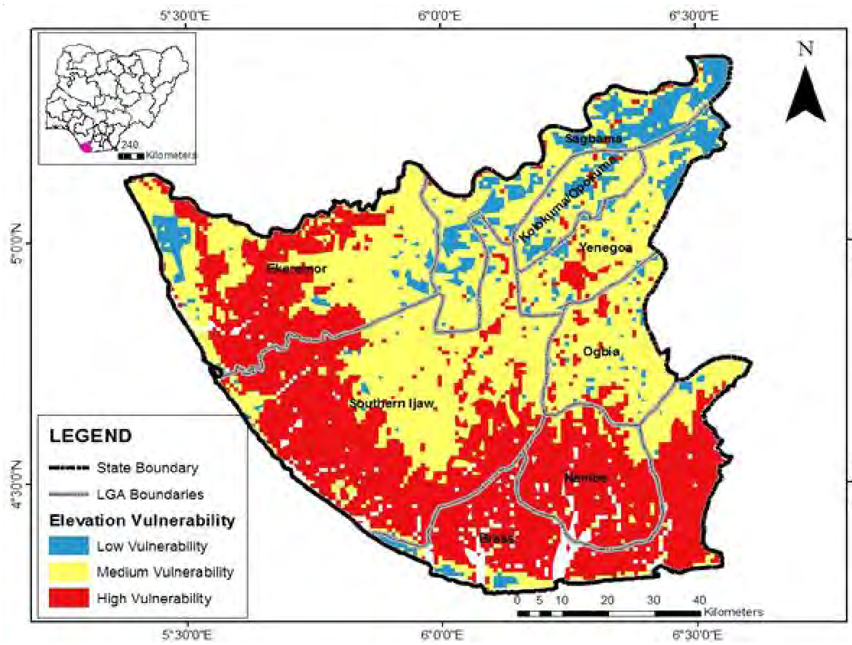
Flood Vulnerability Map based on Elevation

The flood vulnerability level based on elevation is shown in Table 4, Figure 10. It shows that the high vulnerability zone based on elevation was between 1.0m and 12.0m while the moderate vulnerability was between 12.01m and 21.0m. The low vulnerability zone was between 21.01m and 60.0m. The analysis also revealed that the high, moderate and low vulnerability covered 3836.6 km^2 (42.4%), 4363.9km^2 (48.3%) and 853.4 km^2 (9.42%) respectively.

Table 4: Analysis of Elevation Levels and Vulnerability to Flood in Bayelsa State

S.No.	Elevation Level (m)	Spatial Extent (Km^2)	Percentage (%)	Vulnerability Assigned Values	Vulnerability Levels
1	1-5.0	910.4	10.1	3	High Vulnerability
2	5.01-8.0	1659.3	18.3	3	High Vulnerability
3	8.01-12.0	1266.9	14.0	3	High Vulnerability
4	12.01-15.0	1020.9	11.3	2	Moderate Vulnerability
5	15.01-18.0	1618.2	17.9	2	Moderate Vulnerability
6	18.01-21.0	1724.8	19.1	2	Moderate Vulnerability
7	21.01-24.0	651.6	7.2	1	Low Vulnerability
8	24.01-33.0	200.1	2.2	1	Low Vulnerability
9	33.01-60.0	1.7	0.02	1	Low Vulnerability
	Total	**9053.9**	**100.0**		

Figure 10: Elevation Vulnerability of Flood in Bayelsa State



Flood Vulnerability Map and Communities Vulnerability Levels

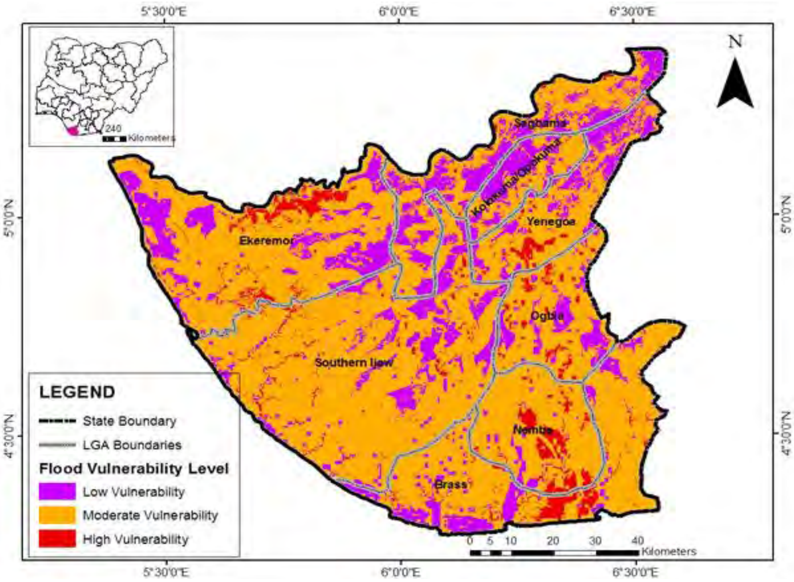
Table 5 and Figure 11 present the flood vulnerability levels and map of Bayelsa State. The analysis showed that the areas that have low vulnerability to flood were 2020.40 km^2 (12.9%) of the entire area. The moderate vulnerability areas covered a spatial extent of 9342.04 km^2 (59.8%), while high vulnerability areas covered 4248.95 km^2 (27.3%). The areas with moderate and high vulnerabilities covered 87.1% of the entire Bayelsa State, which means major part of the study area was prone to flood considering the above factors.

Figure 12 presents the overlay of communities on the flood vulnerability levels of Bayelsa State. It is shown that about 43 (14.98%) communities including Agbalamabugokiri, Agberi, Akassa, Bisagbene, Bolougbene, Bwama, Orukiri, Otokolopiri, Spiffs Town, Tomkiri and Twon had low flood vulnerability levels. The communities with moderate vulnerability feature were about 287 (73.78%) which included Abagbene, Abulabiri, Agudama, Aziama, Brass, Burukiri,

Table 5: Final Flood Vulnerability Levels in Bayelsa State

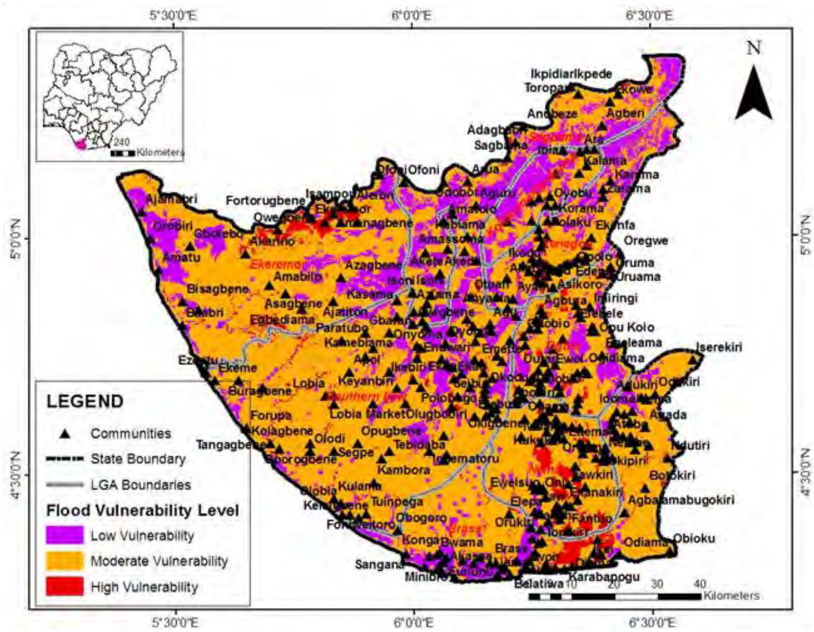
S. No.	Vulnerability Level	Spatial Extent (Km^2)	Percentage (%)
1	Low Vulnerability	2020.40	12.9
2	Moderate Vulnerability	9342.04	59.8
3	High Vulnerability	4248.95	27.2
	Total	**15611.40**	**100**

Figure 11: Final Flood Vulnerability Map of Bayelsa State



Ebelibiri, Ekeremor, Fangbe, Gbaran, Karama, Nembe, Ogboinbiri, Ogbomama, Opuama, Tombia, and Uruama. However, 59 (15.17%) of the entire communities were highly vulnerable to flood in Bayelsa State. These communities include Abolikiri, Akaba, Amarata, Biogbolo, Ekeki, Okokokiri, Okpokiri, Okpoma, Polaku, Swali, Tuluama, Yenagoa and Yenezue-Epie.

Figure 12: Overlay of Communities on Flood Vulnerability Levels in Bayelsa State



Discussion of Findings

The results of the analysis revealed that combination of landuse, proximity to drainage channel, soil texture and elevation of Bayelsa State jointly determined the flood vulnerability levels of each community. 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. 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 reclamation of swamps and river channels due to increase in population and accommodation demands (Chiadikobi *et al.,* 2011; Miller and Hutchins, 2017). More than 85% of communities in Bayelsa State were vulnerable to flood and this suggests that many previous years, these communities might have been suffering from regular inundation especially if the infiltration rate remain high or the river channels overflow their banks. The outcome of this finding on the effect of elevation on flood corroborate the study of Happy et al. (2014) where the slope analysis of their study area was derived from DEM which also confirms the terrain of the study area. Also, Kingsley (2015) arrived at developing flood risk map through ArcGIS environment by overlaying weighted map of various environmental factors. While the vulnerability class showed that places with higher elevation will really not infiltrate the ground and accumulate but it will rather flow downwards to low elevated areas and accumulate. People living within these high elevated (low vulnerability) areas are not really at high risk of flooding but the risk increase along the classes. The finding corroborates the study conducted by Gelleh *et al.*, (2016) where their vulnerability classes were grouped into highly vulnerable, moderately vulnerable and slightly vulnerable. According to Lawal and Umeuduji (2017), and Kar and Hodgson (2008), the wetness index and the roughness index can be used for rapid assessment of potential vulnerability to flooding in a study area.

Conclusion and Recommendations

It can be concluded that flood vulnerability levels in Bayelsa State are jointly determined by four factors, namely landuse, proximity to active channels, elevation and soil texture. The capacity of geospatial techniques have shown that a greater proportional part of Bayelsa State are vulnerable to flood. The study recommends that periodic flood assessment should be encouraged in Bayelsa State, Communities with high and moderate vulnerability to flood should be provided with materials that can make them have adequate preparedness in case of any flood disaster. Environmental education on flood risk mitigation and management should be carried out in the entire study locations.

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