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Flood Vulnerability Assessment of Communities in Akwa Ibom, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Floods are natural events, however, due to various anthropogenic activities coupled with climate change, flooding tends to be both human-induced and natural events. Geographical Information Systems (GIS) techniques can spatially process different physical-environmental parameters in flood risk assessment and the present study determine the extent of vulnerability among the communities in Akwa Ibom State, Nigeria. From the analysis, spatial extent of 932.26 km^2 (13.48%) showed low flood vulnerability level while a spatial extent of 3411.37 km^2 (49.33%) and 2572.09 km^2 (37.19%) indicated moderate and high flood vulnerability levels respectively. At the Local Government Areas (LGAs) level, the low vulnerability covers 932.27 km^2 which represented 13.48% of the entire LGAs in Akwa Ibom State, the medium vulnerability covers a spatial extent of 3411.37 km^2 which represented 49.33% of the entire state while the high vulnerability covers a spatial extent of 2572.09 km^2 which represented 37.19% of the LGAs in the state. The outcome further revealed that Two (2) LGAs are found within the low vulnerability, nineteen (19) LGAs are found within the medium vulnerability while ten (10) LGAs are found within the high vulnerability. At the community level, the analysis indicated that among the 795 communities in the state, 138 of the communities which represent 17.36% of the entire communities have low vulnerability to flood hazards, 429 communities at 53.96% have medium vulnerability level while 228 communities which represent

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28.68% of the entire communities in the state have high flood vulnerability level. The generated maps and identified LGAs and communities at different flood vulnerability zones are useful in all steps of disaster management (prevention, mitigation, preparedness, operations, relief and recovery) and should be considered during initial planning.

Keywords: Flood; GIS; vulnerability assessment; flood vulnerability; Akwa Ibom.

1. INTRODUCTION

The extent of flooding has increased in recent time which is as a result of climate change influenced by anthropogenic activities; therefore, flooding tends to be both human-induced and natural events. As a result, the impacts in recent times cannot be over-emphasized, hindering development in many developing countries. According to Sarkar and Mondal [1], the aftermath of a flood event can be perceived in socio-economic activities, while the extent of such aftermaths is historically increasing globally [2]. Flood events can affect various entities both in urban and rural areas, while the extent of the impacts tends to be very high in urban areas [3]. According to global natural disaster reports, over 2.4 billion individuals have, one way or other, suffered the consequences of flood events. About 165,020 mortalities have been link to the event between 2019 and 2020, as approximated by the United Nations [3]. Furthermore, floods have caused approximately $280 billion in economic damage in Africa over the past two decades [3,4].

An important step to identify the level of flood vulnerability is to map the flood-prone areas to a level. This mapping is very important in the determination of various development policies, such as the development of conservation land, the opening and placement of settlement land, the making of embankments, and other policies. Mapping has been carried out with attention to spatial and temporal precision [5]. Spatial data are required to know the distribution of flood area, while the temporal data are required to know the flood period. Geographical Information Systems (GIS) and Remote Sensing as a science and technology are able to provide a form of management and data of spatial analysis in large numbers. GIS is use to determine the model with selected data so that the views and knowledge of users about the developing situation within, and with GIS mapping of flood prone areas can be done [5].

GIS and remote sensing techniques have become indispensable tools for mapping flood-risk vulnerability [6-8], providing evidence for early warning and emergency response systems. GIS tools in a multi-criteria approach (MCA) combines causative natural factors to derive flood vulnerability classes that support flood risk mitigation [9]. In this vein, Meena & Gupta [10] integrated multiple parameters such as rainfall, slope, drainage density, land use, building density and so on to make deductions. Similarly, Danumah, et al. [11] integrated parameters such as slope, drainage density, type of soil, isohyet, population density, land use and sewer system density. Njoku et al. [12] also combined independent parameters (distance from river, rainfall intensity, elevation, land use, slope and soil- “DRELSS”) to evaluate flood-risk vulnerability. GIS techniques can spatially process different physical-environmental parameters in flood risk assessment and the present study determine the extent of vulnerability among the communities in Akwa Ibom State, Nigeria.

2. METHODS AND MATERIALS

2.1 Study Area

The study area was Akwa Ibom State of Nigeria. Akwa Ibom State is one of the thirty-six states in Nigeria and is located at latitude 4° 33' N and 5° 33' N and longitude 7° 25' E and 8° 25' E (Figs. 1 and 2). It occupies a total land area of 7,246 square kilometres, with a population of 3,920,208 million people (NPC, 2006). Akwa Ibom State is generally a low-lying plain and riverine area with no portion exceeding 175m above sea level. The state is bounded to Atlantic Ocean at the southern end entering into some of its LGAs and communities. The climate features within a tropical monsoon climate of transitional zone of Koppen Af climatic types that varies from the hot equatorial forest type in the southern lowlands to the humid tropics in the northern highlands and the cool montane type in the Obudu plateau area with prolonged and heavy rainy season and very short dry season months in the region.

2.2 Data Gathering and Processing

The imagery of Akwa Ibom state and topographical map will be geo-referenced to world coordinate system (WGS 84) in ArcGIS

10.7. From the imagery, landuse map of the study area was acquired while drainage network, road network and communities imitative from topographical map. Soil texture map of states will also geo-referenced to WGS 84.

i. **Vulnerability Criteria:** This study will make use of ranking methods of the vulnerability factors which is embedded in Analytical Hierarchy Process (AHP) proposed by Saaty [13]. AHP is a multi-criteria basic leadership method, which gives a methodical way to deal with evaluating and incorporating the effects of different variables, including a few dimensions of reliant or autonomous, subjective just as quantitative data [14]. 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 [15]. In positioning strategy, each measure under thought is positioned in the request of the leader's inclination. To create rule esteems for every assessment unit, each factor will be weighted by the evaluated essentialness for causing flood.
ii. **Landuse Map of Selected States:** The geo-referenced Landsat imagery will be exported to Idrisi Selva for the generation of landuse map of the states. Supervised classification technique was adopted with the use of MAXLIKE (Maximum Likelihood Algorithm) module to generate the landuse/land cover types in the area. The area in square kilometer of each landuse type was calculated. The landuse type was converted to vector using Feature to Polygon in ArcGIS environment. The landuse identified were thick vegetation, sparse vegetation, developing area, built up area and water body.
iii. **Proximity to River Channels (Drainage):** The drainage network which determines the proximity to river channels and communities were mapped from the topographical map. These geographic features were digitized and captured as vector data in ArcGIS 10.7.
iv. **Elevation Map:** The elevation map was derived from the height above the mean sea level directly from the Google earth image. A 10 x 10 grid system covering Niger Delta LGAs was created in ArcGIS 10.7 and imported into Google earth interface. The latitude, longitude and height in meters at the center of each grid was recorded and input in Microsoft Excel 2007 Version. The latitude, longitude and height of each point were then imported to ArcGIS 10.7 and were used to generate the elevation map through interpolation method.

The landuse, proximity to river channels (drainage) and elevation maps were reclassified into high vulnerability, moderate vulnerability, low vulnerability and no vulnerability.

i. **Reclassification based on Landuse types***:* Four (4) types of terrain were observed in relation to their distance to the rivers. In terms of landuse map, the thick vegetation was reclassified to low vulnerability, farmland/sparse vegetation to moderate vulnerability while built up area and water bodies as high vulnerability.
ii. **Reclassification based on Drainage Network:** In terms of drainage network, the communities were rated based on their proximity to rivers 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 [16].
iii. **Reclassification based on Elevation:** The elevation map was also reclassified as follows 1.6m-4.6m to high vulnerability, 4.7m-7.6m to moderate vulnerability and above 7.7m to low vulnerability.

The vulnerabilities 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 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 will be regarded as the flood vulnerability map of the selected states in the Niger Delta region considering the landuse, proximity to river channels (drainage network), elevation and soil texture maps of the area. Spatial query in ArcGIS 10.7 will be used to determine the vulnerability levels that each community fall into and also to determine the spatial extent of each vulnerability level.

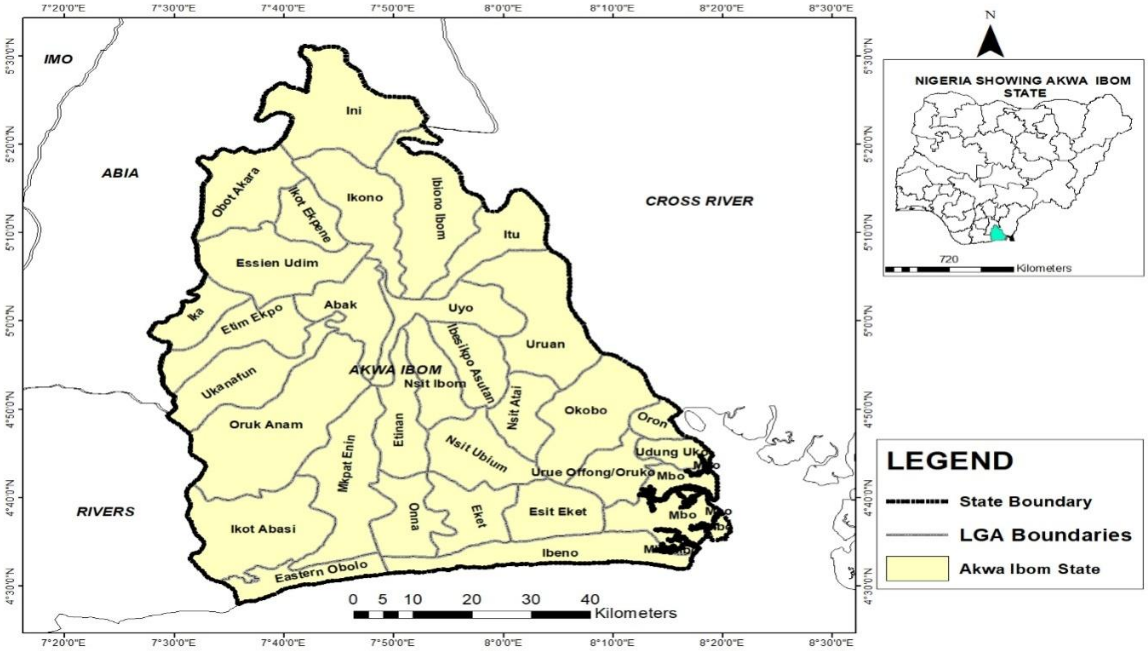

Fig. 1. Overview of Akwa Ibom state showing various LGAs
Source: Generated through ArcGIS 10.7

The results of the classifications and reclassifications were carried out in each of the landuse/land cover, drainage network buffer, soil texture and elevations which will also be explained using descriptive statistics such as percentage and rating. All the study maps were generated through ArcGIS 10.7

3. RESULT AND DISCUSSION

3.1 Slope Percent Rise (%)

The analysis of vulnerability level based slope percent rise domain was presented in Tables 1 and 2 and Figs. 2 and 3, the analysis indicated six (6) categories of slope percent rise in Akwa Ibom state; 0-0.1527%, 1.528-3.173%, 3.174-5.288%, 5.289-8.344%, 8.345-12.575% and 12.756-29.970%. The vulnerability rating of the indicated 3-high vulnerability, 2-moderate vulnerability and 1-low vulnerability. Among the slope percent analysis of Akwa Ibom State, the total spatial extent was 6685.38 km^2. The highest slope percent rise was at 0-1.527% with spatial extent of 2736.65 km^2 (40.93%) and interpreted as high vulnerability while the lowest slope percent rise was at 12.756-29.970% with spatial extent of 58.71 km^2 (0.88%) and interpreted as low vulnerability. From Table 2 and Fig. 3 three slope percent rise vulnerability levels were identified, the low vulnerability level has spatial extent of 240.1 km^2 (3.59%), medium vulnerability has 1324.27 km^2 (19.81%) and high vulnerability has 5121.01 km^2 (76.60%).

3.2 Proximity to Active River Channels

Figs. 4 to 6 presented map of Akwa Ibom State active river channels as part of the analysis for the proximity of active rivers in the state to various LGAs and communities while Tables 3 and 4 showed the details in spatial extent and vulnerability levels. From the analysis, three river buffer distance were identified at 500m, 1000m and 1500m respectively. At the 500m, the spatial extent was 1032 km^2 which represented 35.33% of the total spatial extent of 2921 km^2. At 1000m, the spatial extent was 981 km^2 which represented 33.58% of the total spatial extent while at 1500m, the spatial extent was 908 km^2 which represented 31.09% of the total spatial extent. For vulnerability rating and interpretation, the river buffer distance of 500m was rated 3 and interpreted as high vulnerability, 1000m was rated 2 and interpreted as medium vulnerability while the river buffer distance of 1500m was rated 1 and interpreted as low vulnerability.

3.3 Landuse/Land Covers

Table 5 and Fig. 7 presented the landuse and landcover analysis of Akwa Ibom State. From the analysis, the total landuse and landcover various categories showed a total spatial extent of 6600.66 km^2 and among these, 1170.32 km^2 (17.73%) represented Cropland/Agricultural activities and categorized as moderate vulnerability, 3606.16 km^2 (54.63%) represented the Degraded forest/Developing area and categorized as high vulnerability, 440.90 km^2 (6.68%) represented Thick vegetation/ Plantation and Woodland and categorized as low vulnerability, 680.47 km^2 (10.31%) represented Wetland/Gallery and Riparian vegetation area and categorized as high vulnerability, 236.69 km^2 (3.59%) represented the Mangrove and categorized as moderate vulnerability while 373.85 km^2 (5.66%) and 92.27 km^2 (1.40%) represented the Settlements and Waterbodies respectively and they are all categorized as high vulnerability. From Table 6 and Fig. 8, the overall landuse and land cover vulnerability showed that low vulnerability covered a spatial extent of 440.9 km^2 which is about 6.68% of the total spatial extent while 4776.49 km^2 (72.36%) and 1383.27 km^2 (20.96%) represented the medium and high vulnerability respectively.

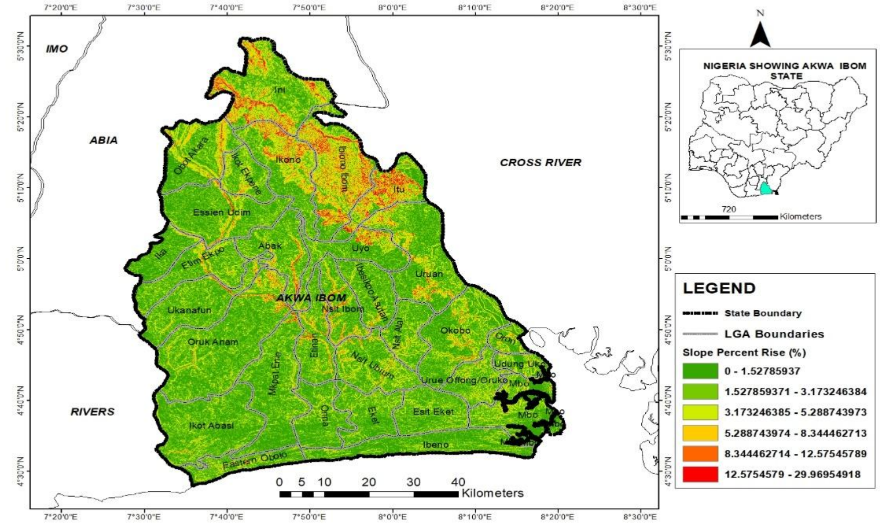

Fig. 2. Slope percent rise of Akwa Ibom

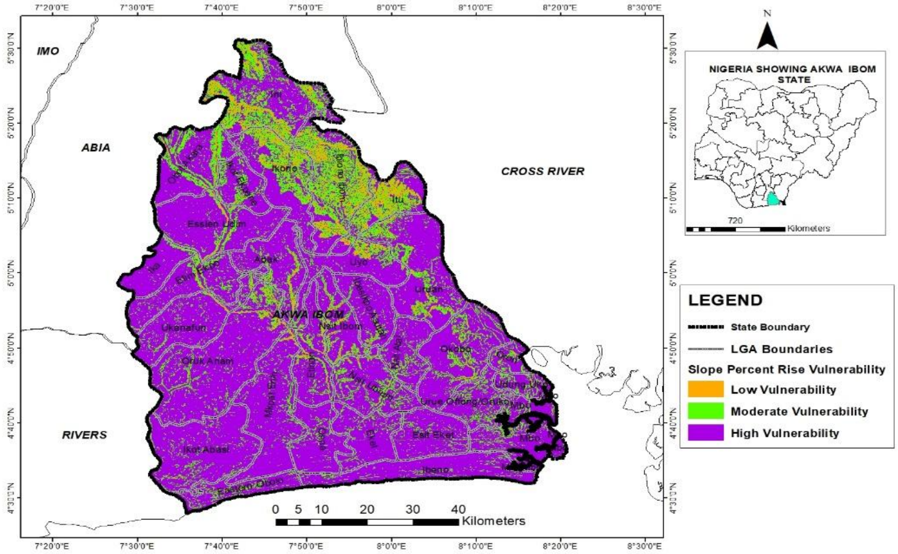

Fig. 3. Slope percent rise vulnerability of Akwa Ibom

Table 1. Slope percent rise (%)

Slope percent rise (%)	Spatial extent (km^2)	Percentage (%)	Vulnerability ratings	Vulnerability interpretations
0-1.527	2736.65	40.93	3	High
1.528-3.173	2384.35	35.67	3	High
3.174-5.288	905.67	13.55	2	Moderate
5.289-8.344	418.62	6.26	2	Moderate
8.345-12.575	181.38	2.71	1	Low
12.756-29.970	58.71	0.88	1	Low
Total	6685.38	100.00		

Table 2. Slope percent rise vulnerability

Slope percent rise vulnerability levels	Spatial extent (km^2)	Percentage (%)
Low	240.1	3.59
Moderate	1324.27	19.81
High	5121.01	76.60
Total	6685.38	100.00

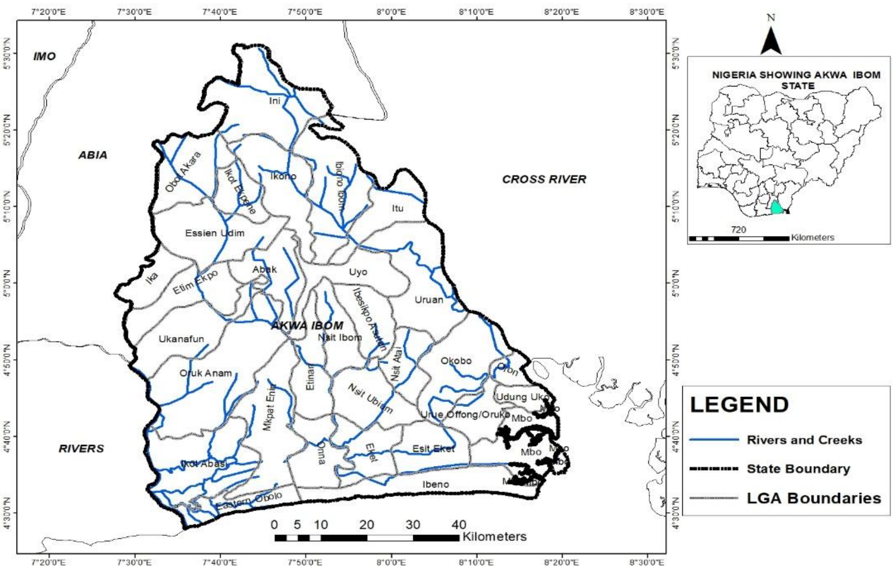

Fig. 4. Active river channels of Akwa Ibom

Table 3. River buffer distance (m) from active river channels

River buffer distance (m)	Spatial extent (km^2)	Percentage (%)	Vulnerability ratings	Vulnerability interpretations
500	1032.00	35.33	3	High
1000	981.00	33.58	2	Moderate
1500	908.00	31.09	1	Low
Total	2921.00	100.00		

Table 4. Proximity to active river channel vulnerability

Proximity to active river channel vulnerability	Spatial extent (km^2)	Percentage (%)
Low	908.00	31.09
Moderate	981.00	33.58
High	1032.00	35.33
Total	2921.00	100.00

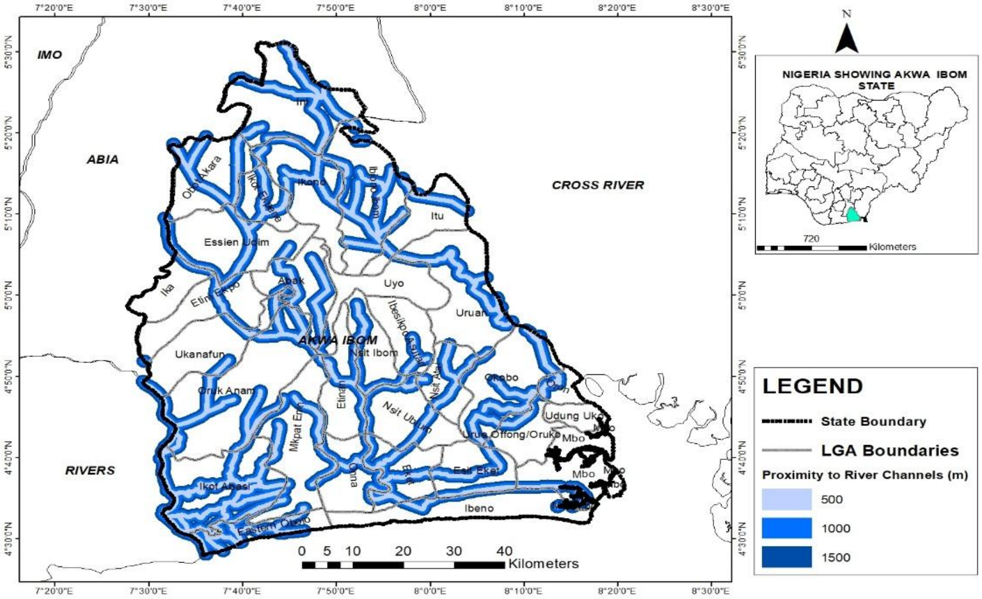

Fig. 5. Proximity to active river channels

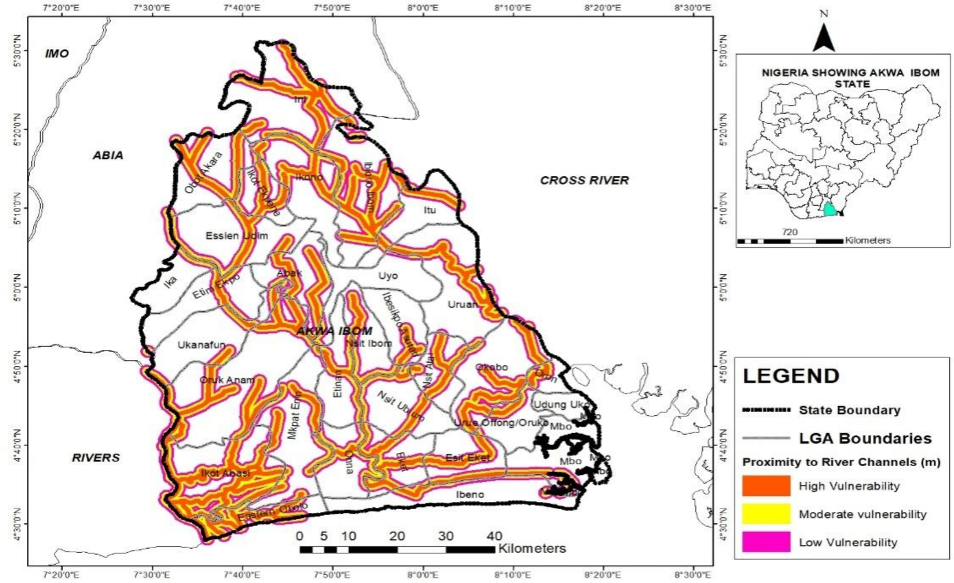

Fig. 6. Proximity to active river channels vulnerability of Akwa Ibom

Table 5. Landuse/land cover analysis

Landuse/Land cover	Spatial extent (km^2)	Percentage (%)	Vulnerability ratings	Vulnerability interpretations
Cropland/Agriculture	1170.32	17.73	2	Moderate
Degraded Forest/Developing Area	3606.16	54.63	3	High
Thick Vegetation/Plantation/Woodland	440.90	6.68	1	Low
Wetland/Riparian Vegetation	680.47	10.31	3	High
Mangrove	236.69	3.59	2	Moderate
Settlements	373.85	5.66	3	High
Waterbodies	92.27	1.40	3	High
Total	6600.66	100.00		

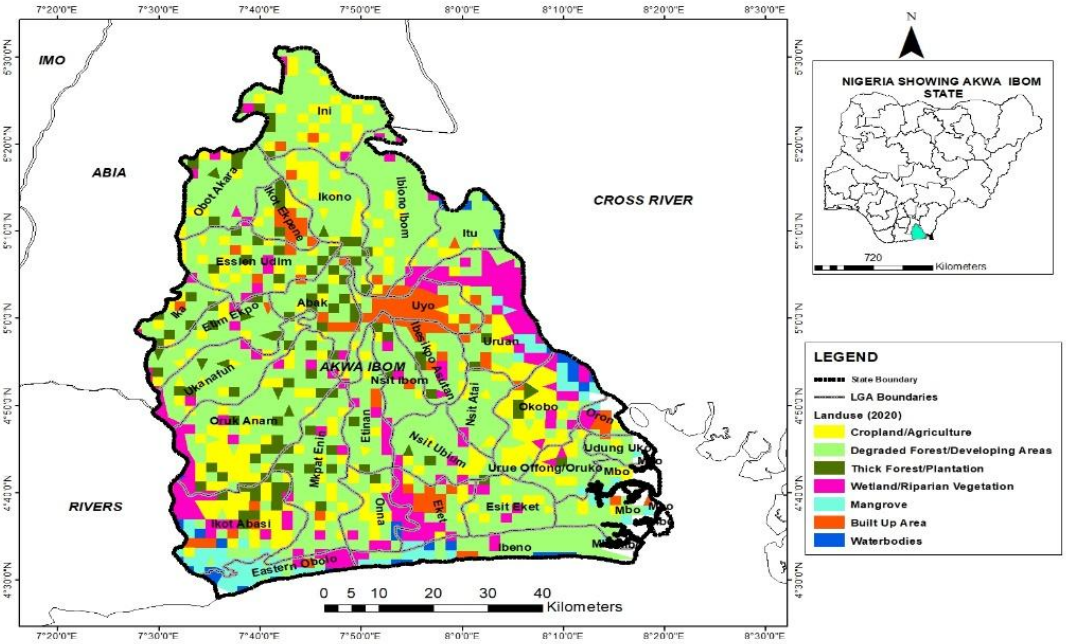

Fig. 7. Landuse and land cover analysis of Akwa Ibom state

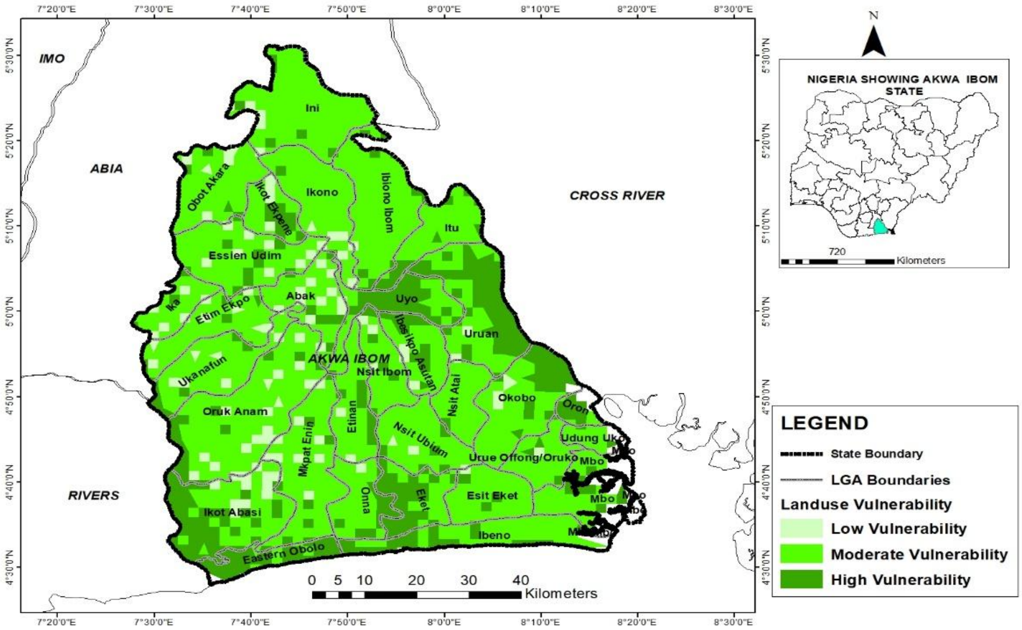

Fig. 8. Landuse and land cover vulnerability of Akwa Ibom state

3.4 Soil Texture

The soil texture analysis of Akwa Ibom State and soil texture vulnerability was presented in Table 7 to 8 and Figs. 9 and 10. From the analysis, three categories of soil texture were identified and spatially distributed across 6470.35 km^2 spatial extent. Among the categories, spatial extent of 4941.75 km^2 (76.38%) represented Coarse soil texture and it is interpreted as low vulnerability, spatial extent of 1004.43 km^2 (15.52%) represented medium soil texture and it is interpreted as medium vulnerability while the spatial extent of 524.17 km^2 (8.10%) represented fine soil texture and it is interpreted as high vulnerability.

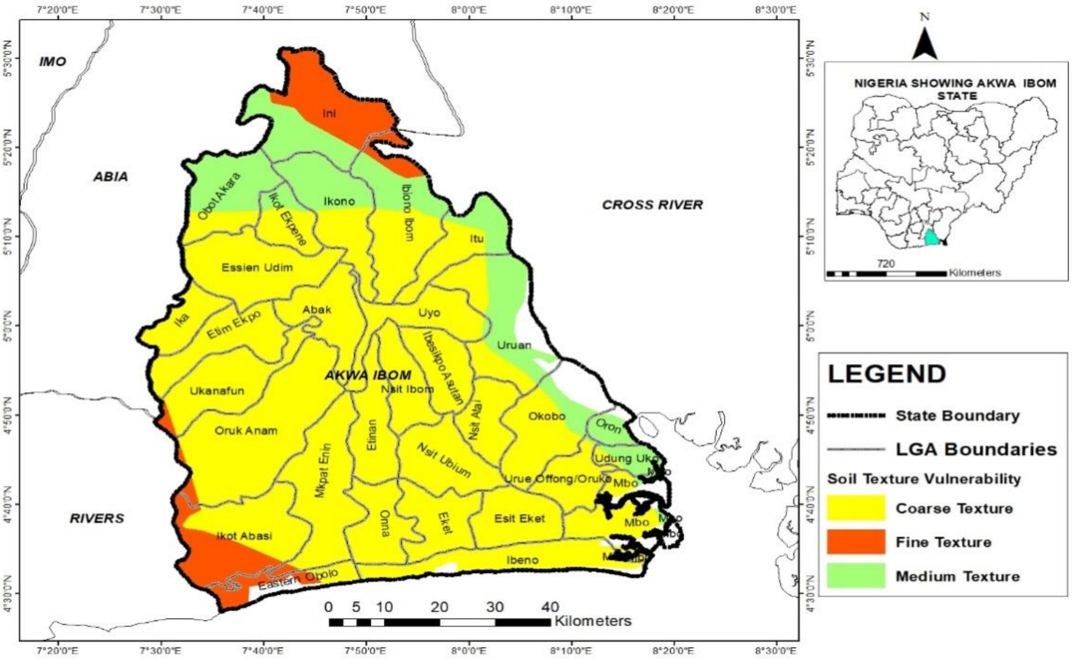

Fig. 9. Soil texture analysis of Akwa Ibom state

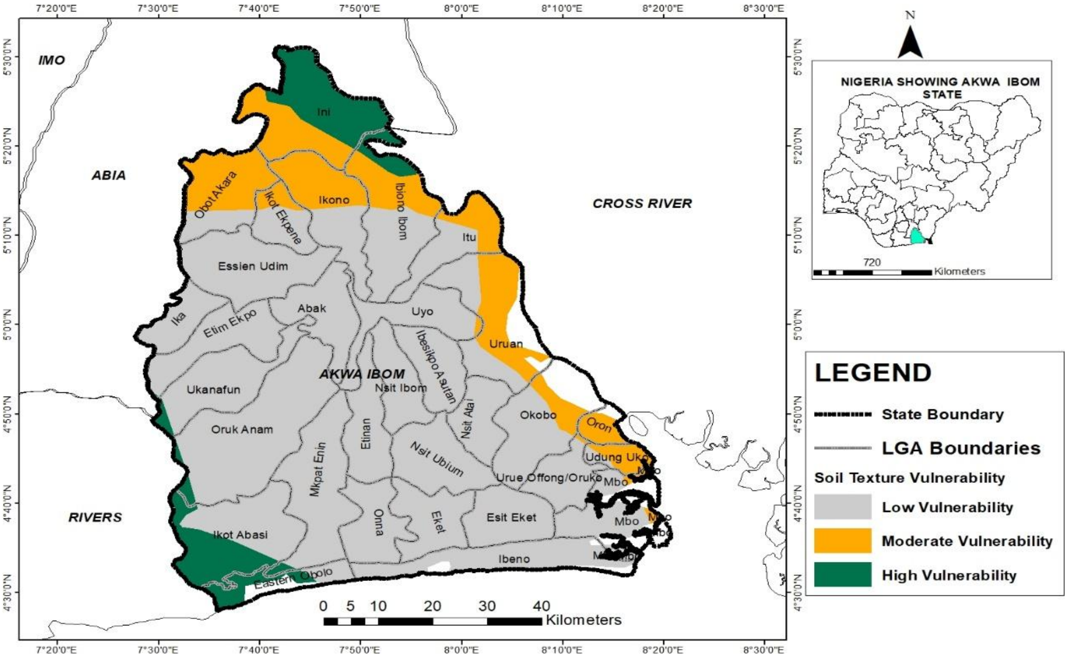

Fig. 10. Soil texture vulnerability analysis of Akwa Ibom state

Table 6. Landuse/land cover vulnerability

Landuse/Land cover vulnerability	Spatial extent (km^2)	Percentage (%)
Low	440.9	6.68
Moderate	4776.49	72.36
High	1383.27	20.96
Total	6600.66	100.00

3.5 Elevation

The analysis of vulnerability level based on elevation (m) domain was presented in Tables 9 and 10, and Figs. 11 and 12. The analysis indicated six (6) categories of elevation level in Akwa Ibom State; 0-21m, 21.01 - 39m, 39.01 - 57m, 57.01 - 76m, 76.01 - 99m, and 99.01 - 144m. At elevation 0-39m, the spatial extent covered was 3576.11 km^2 (53.1%) with vulnerability rating of 3 which implies high vulnerability. At the 39.01-76m, the spatial extent covered was 2280.67 km^2 (33.87%) with vulnerability rating of 2 which implies medium vulnerability. At elevation ranged from 76.01m – 144m, the spatial extent covered was 877.39 km^2 (13.03%) with vulnerability rating of 1 which implies low vulnerability.

3.6 Rainfall Volume

The rainfall volume was analyzed as the domain for climate change influence on the flood vulnerability level of Akwa Ibom State and the outcome of the analysis was presented in Tables 11 and 12 and Figs. 13 and 14. From the analysis, rainfall volume of 1957.077mm – 2104.420mm covers a spatial extent of 3279.24 km^2 which represented 48.68% of the total spatial extent of 6735.76 km^2. In terms of vulnerability rating, the rainfall volume was rated 1 and it is interpreted as low vulnerability. For rainfall volume of 2104.421mm – 2239.186mm, the spatial extent covered was 2425.32 km^2 which represented 36.01% of the total spatial extent while the vulnerability rating was 2 and it is interpreted as medium vulnerability. For rainfall volume of 2239.187 mm -2415.280 mm, the spatial extent covered was 1031.2 km^2 which represented 15.31% of the total spatial extent while the vulnerability rating was 3 and it is interpreted as high vulnerability.

3.7 Communities Flood Vulnerability Levels

The flood vulnerability at the LGAs level and community level for Akwa Ibom State was analysed and presented in Tables 13 to 15 and Figs. 15-18. From the analysis, spatial extent of 932.26 km^2 (13.48%) showed low flood vulnerability level while a spatial extent of 3411.37 km^2 (49.33%) and 2572.09 km^2 (37.19%) indicated moderate and high flood vulnerability level respectively. At the LGAs level, the low vulnerability covers 932.27 km^2 which represented 13.48% of the entire LGAs in Akwa Ibom State, the medium vulnerability covers a spatial extent of 3411.37 km^2 which represented 49.33% of the entire state while the high vulnerability covers a spatial extent of 2572.09 km^2 which represented 37.19% of the LGAs in the state. The outcome further revealed that Two (2) LGAs are found within the low vulnerability, Nineteen (19) LGAs are found within the medium vulnerability while Ten (10) LGAs are found within the high vulnerability. At the community level, the analysis indicated that among the 795 communities in the state, 138 of the communities which represent 17.36% of the entire communities have low vulnerability to flood hazard, 429 communities at 53.96% have medium vulnerability level while 228 communities which represent 28.68% of the entire communities in the state have high flood vulnerability level.

Table 7. Soil texture analysis

Soil Texture	Spatial extent (km^2)	Percentage (%)	Vulnerability ratings	Vulnerability interpretations
Coarse Texture	4941.75	76.38	1	Low
Medium Texture	1004.43	15.52	2	Moderate
Fine Texture	524.17	8.10	3	High
Total	6470.35	100.00		

Table 8. Soil texture vulnerability

Soil texture vulnerability	Spatial extent (km^2)	Percentage (%)
Low	4941.75	76.38
Moderate	1004.43	15.52
High	524.17	8.10
Total	6470.35	100.00

Table 9. Elevation analysis

Elevation (m)	Spatial extent (km^2)	Percentage (%)	Vulnerability ratings	Vulnerability interpretations
0-21	1918.74	28.49	3	High
21.01-39	1657.37	24.61	3	High
39.01-57	1355.95	20.14	2	Moderate
57.01-76	924.72	13.73	2	Moderate
76.01-99	627.75	9.32	1	Low
99.01-144	249.64	3.71	1	Low
Total	6734.17	100.00		

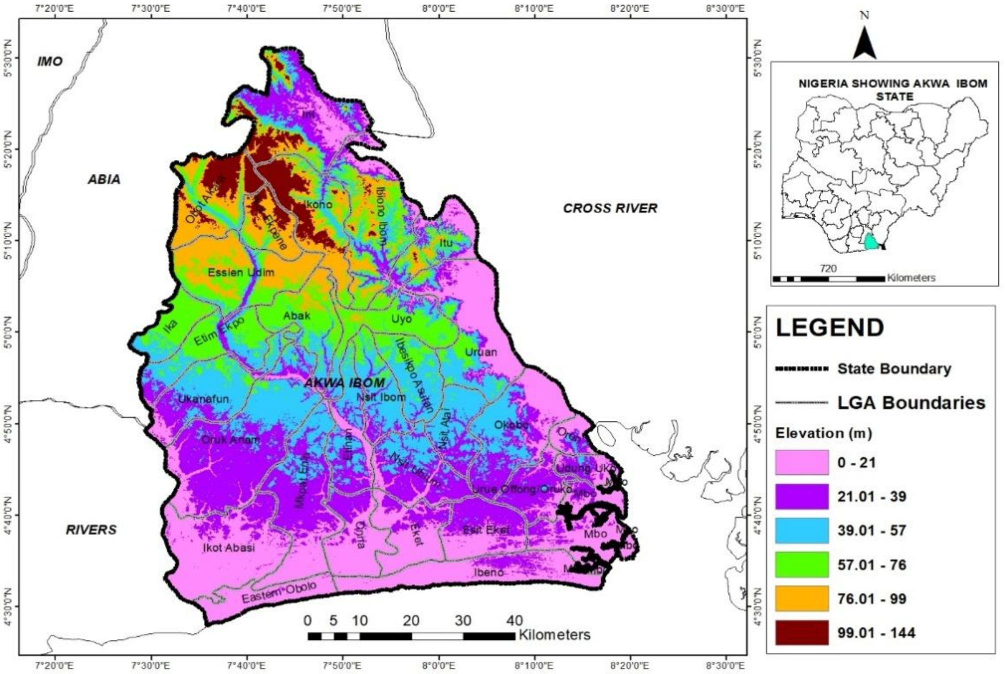

Fig. 11. Elevation analysis of Akwa Ibom state

Table 10. Elevation vulnerability

Elevation vulnerability	Spatial extent (km^2)	Percentage (%)
Low	877.39	13.03
Moderate	2280.67	33.87
High	3576.11	53.10
Total	6734.17	100.00

Table 11. Rainfall volume analysis

Rainfall volume (mm)	Spatial Extent (km^2)	Percentage (%)	Vulnerability ratings	Vulnerability interpretations
1957.077-2032.545	1761.4	26.15	1	Low
2032.546-2104.420	1517.84	22.53	1	Low
2104.421-2174.498	1621.34	24.07	2	Moderate
2174.499-2239.186	803.98	11.94	2	Moderate
2239.187-2307.467	672.45	9.98	3	High
2307.468-2415.280	358.75	5.33	3	High
Total	6735.76	100.00		

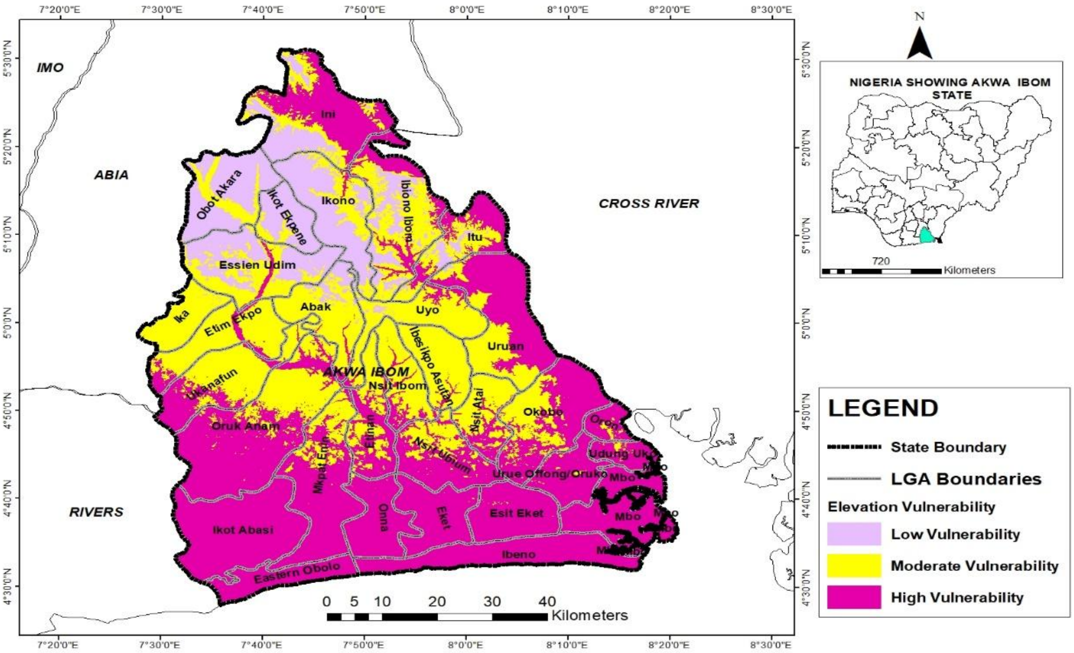

Fig. 12. Elevation vulnerability analysis of Akwa Ibom state

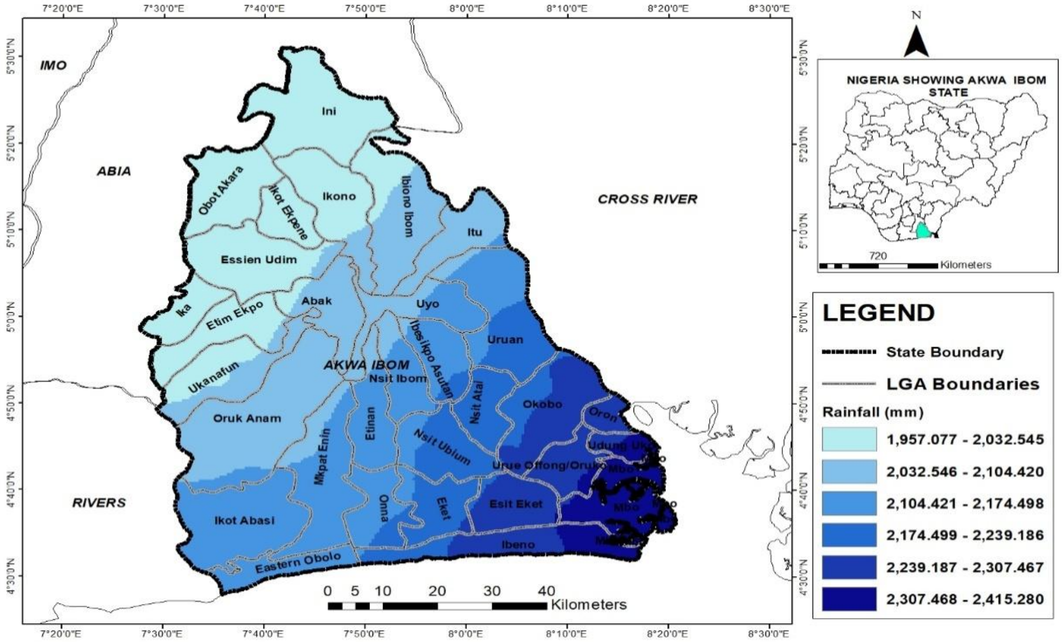

Fig. 13. Rainfall volume (mm) of Akwa Ibom state

Table 12. Rainfall vulnerability

Rainfall vulnerability	Spatial extent (km^2)	Percentage (%)
Low	3279.24	48.68
Moderate	2425.31	36.01
High	1031.21	15.31
Total	6735.76	100.00

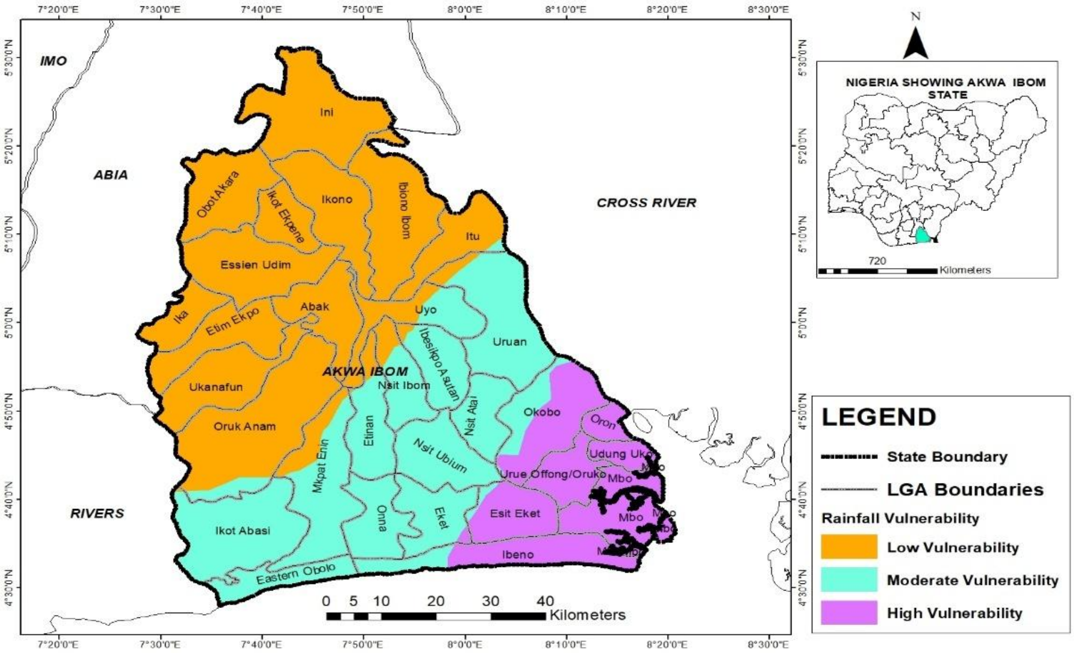

Fig. 14. Rainfall vulnerability of Akwa Ibom state

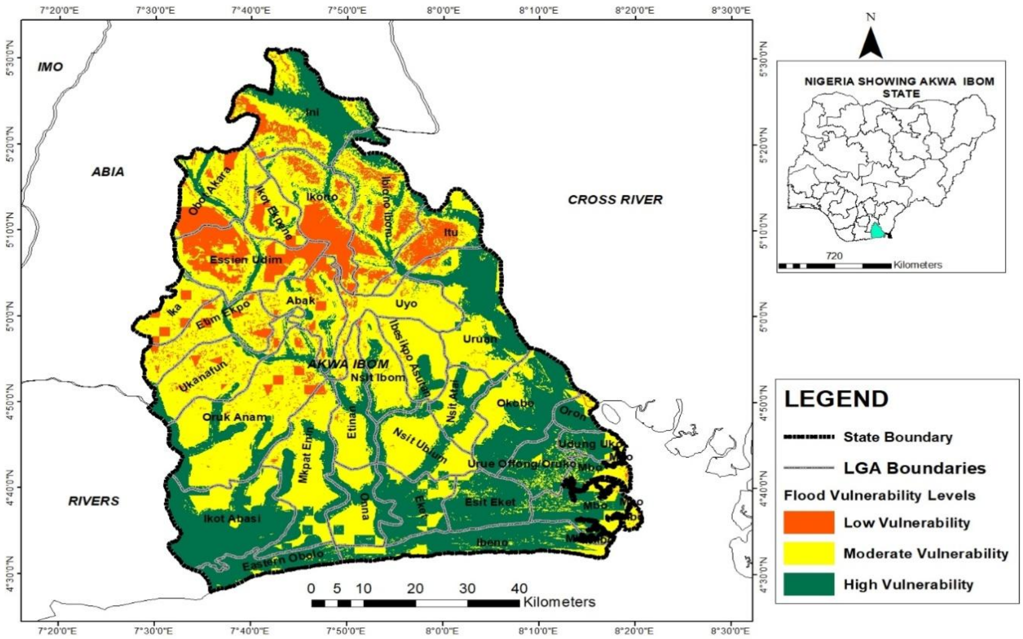

Fig. 15. Flood vulnerability levels of Akwa Ibom state

Table 13. Final flood vulnerability levels

Flood vulnerability levels	Spatial extent (km^2)	Percentage (%)
Low	932.26	13.48
Moderate	3411.37	49.33
High	2572.09	37.19
Total	6915.73	100.00

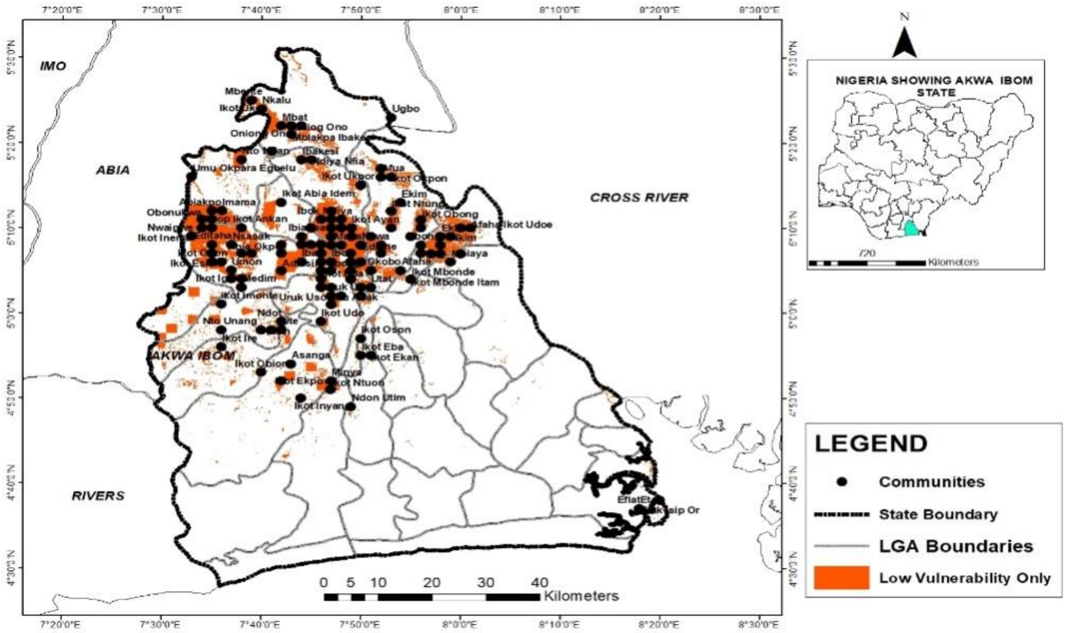

Fig. 16. Flood vulnerability at community level (low vulnerability communities)

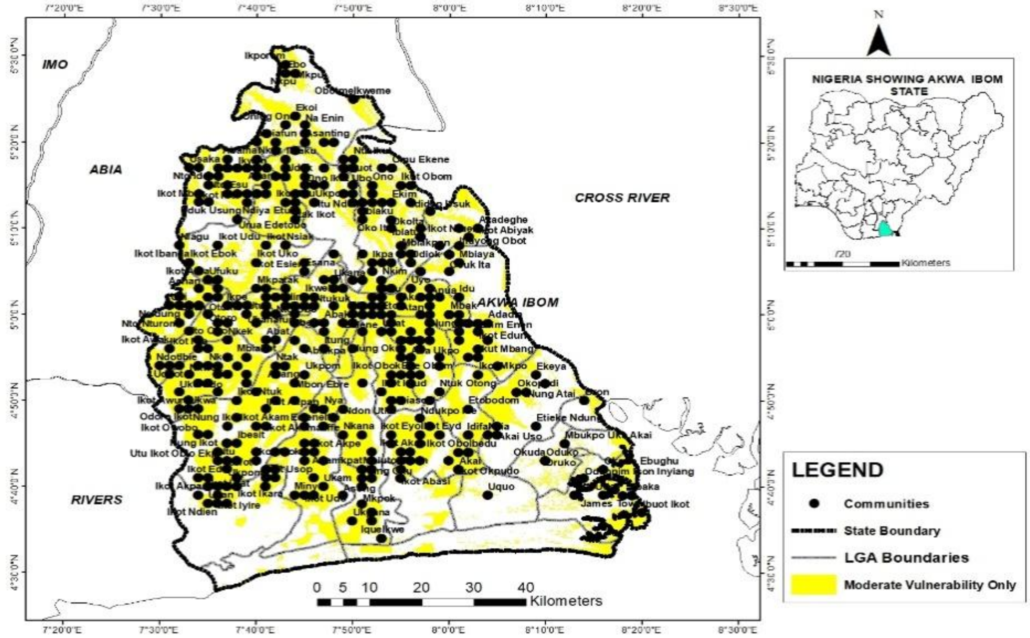

Fig. 17. Flood vulnerability at community level (medium vulnerability communities)

Table 14. Summary of flood vulnerability levels at LGAs and communities

Communities flood vulnerability levels	Number of LGAs	Number of communities	Percentage (%)
Low	2	138	17.36
Moderate	19	429	53.96
High	10	228	28.68
Total		795	100.00

Table 15. Spatial flood vulnerability of LGAs in Akwa Ibom state

LGAs	Low vulnerability		Moderate vulnerability		High vulnerability		Total LGA SE (km^2)	Percentage (%)
	SE (km^2)	%C-LGA	SE (km^2)	%C-LGA	SE (km^2)	%C-LGA		
Abak	48.13	5.16	126.71	3.71	24.92	0.97	199.76	100.00
Eastern Obolo	1.17	0.12	10.13	0.30	109.45	4.26	120.75	100.00
Eket	0.00	0.00	38.91	1.14	128.65	5.00	167.56	100.00
Esit Eket	0.00	0.00	15.46	0.45	152.6	5.93	168.06	100.00
Essien Udim	184.09	19.75	125.95	3.69	22.25	0.87	332.29	100.00
Etim Ekpo	45.51	4.88	153.57	4.50	16.05	0.62	215.13	100.00
Etinan	3.78	0.41	121.11	3.55	50.81	1.98	175.70	100.00
Ibeno	6.03	0.65	49.3	1.45	189.19	7.36	244.52	100.00
Ibesikpo Asutan	1.67	0.18	127.17	3.73	26.06	1.01	154.90	100.00
Ibiono-Ibom	96.77	10.38	179.81	5.27	80.03	3.11	356.61	100.00
Ika	28.42	3.05	87.27	2.56	2.83	0.11	118.52	100.00
Ikono	141.64	15.19	120.31	3.53	25.7	1.00	287.65	100.00
Ikot Abasi	0.06	0.01	75.44	2.21	284.15	11.05	359.65	100.00
Ikot Ekpene	33.44	3.59	81.36	2.38	7.85	0.31	122.65	100.00
Ini	63.68	6.83	150.23	4.40	171.45	6.67	385.36	100.00
Itu	62.91	6.75	76.84	2.25	38.7	1.50	178.45	100.00
Mbo	19.25	2.06	90.43	2.65	122.79	4.77	232.47	100.00
Mkpat-Enin	8.41	0.90	195.43	5.73	127.5	4.96	331.34	100.00
Nsit-Atai	0.14	0.01	84.94	2.49	49.33	1.92	134.41	100.00
Nsit-Ibom	3.85	0.41	105.86	3.10	32.99	1.28	142.70	100.00
Nsit-Ubium	0.28	0.03	146.39	4.29	59.27	2.30	205.94	100.00
Obot Akara	83.70	8.98	139.46	4.09	31.31	1.22	254.47	100.00
Okobo	1.25	0.13	94.67	2.78	204	7.93	299.92	100.00
Onna	0.00	0.00	87.79	2.57	74.55	2.90	162.34	100.00
Oron	3.21	0.34	10.16	0.30	40.94	1.59	54.31	100.00
Oruk Anam	37.18	3.99	363.53	10.66	130.53	5.07	531.24	100.00
Udung-Uko	1.30	0.14	17.15	0.50	42.33	1.65	60.78	100.00
Ukanafun	27.73	2.97	193.25	5.66	31.07	1.21	252.05	100.00
Uruan	13.16	1.41	154.28	4.52	181.94	7.07	349.38	100.00
Urue-Offong	0.00	0.00	24.47	0.72	102.62	3.99	127.09	100.00
Uyo	15.52	1.67	163.99	4.81	10.23	0.40	189.74	100.00
	932.27	100.00	3411.37	100.00	2572.09	100.00	6915.73	100.00

Key: SE-Spatial Extent, %C-LGA-Percentage Cover within the LGA

The study adopted various physical environmental domains such as slope, elevation, landuse and landcover, proximity to river channel and soil texture to establish the flood vulnerability levels of Akwa Ibom state [4]. The established levels were categorized into low, medium and high vulnerability and their spatial extent cover was also established. The outcome of the study showed similarity with previous studies conducted using various physical environmental domains. Through domains such as landuse, elevation and proximity to river channel, Afolabi et al. [4] established the vulnerability categories of communities in Isoko North LGAs low, medium and high vulnerability. Chukwuma et al. [17] through conditional factors such as slope, landuse, elevation and soil texture, the vulnerability level of LGAs in Anambra state was determined. The approach adopted by this study; that is, the use of RS and GIS is a common approach to flood modelling. This was corroborated by various studies including that of Bello and Ogedegbe [18], Orimoogunje et al., 2016 and Umar and Gray [19]. On the Landuse/Landcover, the activities with high vulnerability reported for these studies; that is, settlement, waterbodies, rocky land and sandy area are similar to those reported by Onuigbo et al. [20]. Wizor and Week [21] opined that various anthropogenic activities affect the landuse and landcover of an area which is capable of increasing the exposure. Among various landuse/landcover categories reported for this study, settlement was rated the highest among

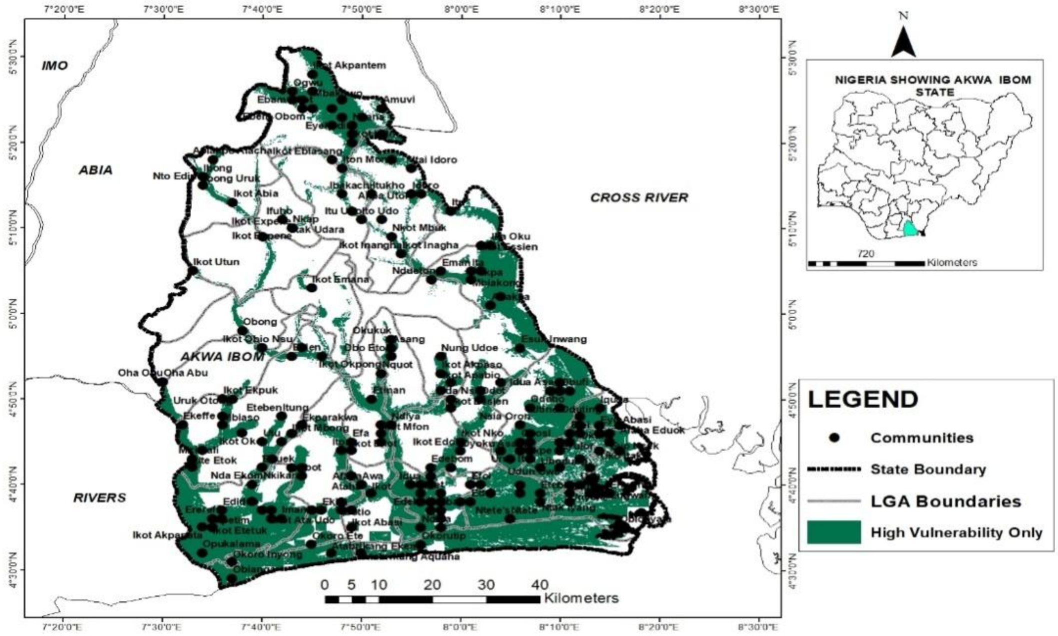

Fig. 18. Flood vulnerability at community level (high vulnerability communities)

the high vulnerability for landuse/landcover. Changes in land use due to urbanization increase flood susceptibility (Kaspersen et al., 2015) as urbanization is largely associated with the removal of soil and vegetation and these are important factors for limiting surface runoff [22,23]. The outcome on elevation showed similarity with that of Berezie et al. (2019) which was able to establish the vulnerability level due to elevation of their study area. LGAs like Ikot Abasi, Eket, Esit Eket and Onna are among the highly vulnerable areas due to elevation characteristics. The vulnerability rating scale adopted for this study which was based on high (3), medium (2) and low (1) vulnerability was similar to those adopted by Afolabi et al. [4] and Berezie et al. (2019).

At the LGAs level, the two (2) LGAs found to be low flood vulnerability include Essien Udim and Ikono. The nineteen (19) LGAs found to be medium flood vulnerability include; Abak, Etim-Ekpo, Etinan, Ibesikpo-Asutan, Ibiono-Ibom, Ika, Ikono, Ikot Ekpene, Itu, Nsit-Atai, Mkpat-Enin, Nsit-Ibom, Nsit-Ubium, Obot-AkaraOron, Onna, Oruk Anam, Ukanafun, Udung-Uko and Uyo. Ten (10) LGAs found to be high flood vulnerability include Eastern Obolo, Eket, Esit-Eket, Ibeno, Ikot Abasi, Ini, Mbo, Okobo, Uruan and Urue-Offong/Oruko.

The outcome of the study corroborated with that of Berezie et al. (2019) which was conducted for LGAs and communities in Bayelsa State. Also, the outcome of the study showed similarity with that of Ozim et al. [24] where the LGAs identified as high vulnerability are similar with the present study. From the study, Uyo was categorized into medium vulnerability with spatial extent of 163.33 km^2 (6.38%) out of the 2572.09 km^2 of the total area. At the communities' level, 138 communities were found to be with low vulnerability level while 429 communities and 228 communities were found to be within medium and high vulnerability level. Njoku et al. [9] opined that population density of a communities influences the risk to flood vulnerability and accordingly, Lagos State is the most vulnerable because of LGAs with high population densities within high flood-risk zones. Other states with communities exposed to high flood-risk vulnerability include Rivers, Kogi, Cross River, Akwa Ibom, Anambra, and Delta.

4. CONCLUSION AND RECOMMENDATIONS

The Geospatial approach of the study further encourages the possibility of establishing the flood vulnerability level of an area through domains such as land use, elevation, and proximity to river bodies (drainage). The assessment through ArcGIS concluded that Two (2) LGAs are found within the low vulnerability, nineteen (19) LGAs are found within the medium while Ten (10) LGAs are high vulnerability. Also, among the 795 communities in the state, 138

(17.36%) communities are low vulnerability to flood hazard, 429 (53.96%) are medium vulnerability level and 228 (28.68%) communities are high flood vulnerability level. The maps and lists of LGAs at different flood vulnerability zones are useful in all steps of disaster management (prevention, mitigation, preparedness, operations, relief and recovery) and should be considered during initial planning. Various human activities that can contribute to increase vulnerability such as building on river channel should be adequately monitored and prevented.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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