Flood Vulnerability and Mitigation Strategies of Communities in Delta State, Nigeria

Jumbo, S. A [1], Obafemi, A. A [1,2], Eludoyin, O. S [1,2]

[1]Centre for Disaster Risk Management and Development Studies, University of Port-Harcourt, Nigeria.

[2]Department of Geography and Environmental Management, University of Port Harcourt, Nigeria

Corresponding Author: ayeindajumbo@gmail.com

Abstract: - One of the major approaches to flood management in Nigeria is through mapping of various areas through the use of Geographic Information System (GIS) and its techniques in creating flood vulnerability map of an area which is important for the development of mitigation strategies. The study accessed the flood vulnerability and mitigation strategies of communities in Delta State, Nigeria. Through series of physical environment domains such as relief, proximity to active river channels, landuse/land cover, soil texture, and elevation, flood vulnerability of Delta state was established at town/communities' level. The finding revealed that 281 (40.67%) communities have low vulnerability, 328 (47.47%) communities have high vulnerability and 82 (11.87%) communities have high vulnerability to flood events. Also, communities raised their house foundation as mitigation measures supported by Government provision of drainage system while both measures were perceived effective. There is need for effective collaboration between the Delta State government and the national, state and local agencies for development of flood policy plan towards flood disaster management in the state.

Key Words: - ***Geographic Information System, Flood Vulnerability Level, Mitigation, Delta State.***

I. Introduction

Vulnerability assessments have been recognized as being crucial to disaster management and are conducted to understand potential for loss, focusing on nature of the hazard and who and what are exposed (Cutter et al., 2001; Ukoje & Achegbulu, 2022). Identifying vulnerability is important for the development of mitigation strategies and adaptation policies necessary for sustainable development (Ukoje & Achegbulu, 2022). Vulnerability mapping can help guide flood plain zoning which like other non-structural flood control measures, are usually given less attention by environmental managers (Ukoje & Achegbulu, 2022). Geographic Information System (GIS) is an important tool for mapping spatial distribution of exposure and vulnerability.

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It facilitates input, storage, management, analysis, integration, and output of spatial data which can help real time decision making and strategic planning for effective risk management and hazard preparedness particularly for meteorological and flood hazards (Chau et al., 2013; Ukoje & Achegbulu, 2022). GIS can be used in assessing flood impacts and as a tool that can assist flood plain managers in identifying flood prone areas, helping also in real time monitoring, early warning and quick damage assessment of flood disasters (Ukoje & Achegbulu, 2022).

In Nigeria, flooding displaces more people than any other natural disaster with an estimated 20% of the population at risk (Etuonovbe 2011; Cirella and Iyalomhe, 2018). This perennial problem consistently results in death and displacement of communities. The number of flood-related fatalities has varied significantly from flood-to-flood with the percentage of displaced versus killed persons not conclusive in the literature. In Nigeria, flood disaster has been perilous to people, communities and institutions. Flood disaster is not a recent phenomenon in Nigeria. Its destructive tendencies are sometimes enormous. Its occurrences have been reported in Ibadan (1985, 1987, 1990 etc.), Osogbo (1992; 1996; 2002), Yobe (2000) and Akure (1996; 2000; 2002; 2004; 2006). The coastal cities of Lagos, Port Harcourt, Calabar, Uyo, and Warri among others have many times experienced incidents that have claimed many lives and properties worth millions of dollars (Folorunsho and Awosika 2001; Ologunorisa, 2004; Magami et al., 2014).

In managing the flood events in Nigeria, several approaches have been adopted in accessing the vulnerable people and their areas for effective flood management. One of the major approaches to flood management in Nigeria is through Mapping of various areas through the use of Geographic Information System (GIS) and its techniques in creating flood vulnerability map of an area (Berezi et al., 2019; Wizor & Week, 2020; Atagbaza et al., 2020; Awodumi, 2020; Gift et al., 2020; Okorafor et al., 2021; Afolabi et al., 2022). Among many of the Niger Delta States, Delta state have the highest communities at risk when water overflow their banks to about 500m. This is because the State has the highest number of rivers and many communities lie at the banks of these rivers (Amangabara and Obenade 2015). This study therefore further examines the flood vulnerability of the state at the community level based on physical-environmental indices as well as the mitigation measures adopted by communities in the state.

Materials and Methods

Study Area

The state lies approximately between 5°00' and 6°45' E and 5°00' and 6°30' N (Figure 1) (Ebewor, 2020). It is geographically located in Nigeria's Midwest, bounded in the north and west by Edo State, the east by Anambra, Imo, and Rivers States, southeast by Bayelsa State, and on the southern extreme is the Bight of Benin which covers about 160 kilometres of the state's coastline. Delta State is generally low-lying without any remarkable hills. The state has a wide coastal belt inter-laced with rivulets and streams, which form part of the Niger Delta. The State covers a landmass of about 18,050 km2 (6,970 sq mi), of which more than 60% is land. the state is divided between the Central African mangroves in the coastal southwest and the Nigerian lowland forests in most of the rest of the state as a small portion of the Niger Delta swamp forests are in the far south. The other important geographical features are the River Niger and its distributary, the Forçados River, which flow along Delta's eastern and southern borders, respectively; while fellow Niger distributary, the Escravos River, runs through Warri and the coastal areas are riddled with dozens of smaller Niger distributaries that make up much of the western Niger Delta.

Fig.1. Overview Of Delta State Showing Various Major Towns

1.1 Source of Data

This study employed the use of both primary and secondary data.

The primary data included:

i. Landuse map of Delta State acquired from the Landsat imagery of 30 m × 30 m.
ii. Drainage Network, Road Network, Communities location, and Soil map extracted from the topographic map of 1:100,000 of the study area.
iii. Questionnaire (Mitigation Measures Questionnaire-MMQ)

The secondary data included:

i. Population data for 2016 of the communities from Edo State (NPC, 2016).
ii. Topographic guide of the investigation zone from Surveyor General's Office, Ministry of Lands and Survey, Delta State.
iii. Landsat symbolism of 30 m × 30 m of 2015 got from the US Geological Survey.

1.2 Data Analysis

i. *Desktop Analysis with ArcGIS:* The imagery of Delta States and topographical map was geo-referenced to world coordinate system (WGS 84) in ArcGIS 9.3. 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 was also geo-referenced to WGS 84.

a. *Vulnerability Criteria:* The study adopted the 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 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 (Bapalu and Sinha, 2006; Berezi, 2019). 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 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 was weighted by the evaluated essentialness for causing flood.

b. *Landuse Map of Selected States:* The geo-referenced Landsat imagery was 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 land use identified were thick vegetation, sparse vegetation, developing area, built up area and water body.
c. *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 10.6.
d. *Elevation/Relief 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 WNDSs was created in ArcGIS 9.3 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 2016 Version. The latitude, longitude and height of each point were then imported to ArcGIS 9.3 and were used to generate the elevation map through interpolation method.

The vulnerabilities levels were assigned values 3, 2, 1 to high vulnerability, moderate/medium 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 9.3 with the use of UNION MODULE. Reclassification method was also applied to have high vulnerability, moderate vulnerability, low vulnerability and very low vulnerability. The output of this map was regarded as the flood vulnerability map of the Delta State considering the landuse, proximity to river channels (drainage network), elevation and soil texture maps of the area. Spatial query in ArcGIS 9.3 was used to determine the vulnerability levels that each community fell into and also used to determine the spatial extent of each vulnerability level.

ii. Mitigation Measures Questionnaire-MMQ: MMQ was administered to respondents from Agoloma, Abari and Patani communities in Patani Local Government Area and Olomoro, Aviara and Oleh in Isoko South Local Government Area. The study involved 120 respondents with feedbacks of 93% (112 respondents). The retrieved questionnaire was coded and subjected to Statistical Package for the Social Sciences (SPSS) for proper analysis. The retrieved questionnaire coding was done with MS Excel before being transferred to the Data entry of SPSS window (Version 22). The data of the study was analyzed through descriptive statistics. Descriptive statistics tool such as frequency counts, percentages of response and chats was adopted for the analysis. The use of such statistics allows the researcher to present the evidence of the study in a way that can be understandable and makes conclusion concerning the variables of study.

II. Result and Discussion

2.1 Flood Vulnerable Levels of the Delta State

Proximity to Active River Channels: The proximity of various LGAs and communities in Delta state to active river channels were analysed based on active river channel of the state, drainage buffering analysis and proximity analysis and was presented in Table 1 and Figure 2 and 3. From the proximity analysis, a river buffer distance of 500m covered a spatial area of 2561.4 km^2 representing 37.85% of the total area which is interpreted as high vulnerability under vulnerability rating of 3. At 1000m river buffer distance, the area covered was 2270.65 km^2 representing 33.55% of the total area which is interpreted as moderate/medium vulnerability under vulnerability rating of 2. At 1500m river buffer distance, the area covered was 1935.11 km^2 representing 28.60% of the total area which is interpreted as low vulnerability under vulnerability rating of 1.

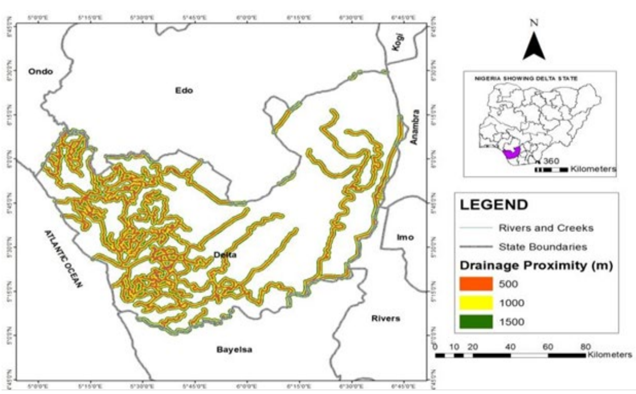

Fig.2. Drainage Buffering Analysis for the Active Channels of Delta State

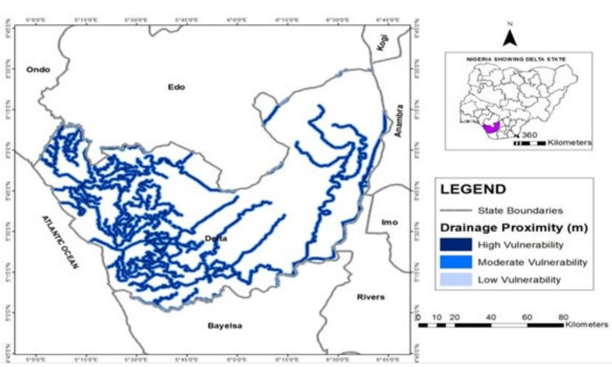

Fig.3. River Channels Proximity Analysis

Table.1. River Buffer Distance (m) from Active River Channels

River Buffer Distance (m)	Spatial Extent (Sq km)	Percentage (%)	Vulnerability Ratings	Vulnerability Interpretations
500	2561.4	37.85	3	High
1000	2270.65	33.55	2	Moderate
1500	1935.11	28.60	1	Low
Total	6767.16	100.00		

Landuse/Land Covers: The landuse and landcover analysis of the LGAs and communities across the Delta state was presented in Table 2 and Figure 4 and 5. From the analysis, Cropland covers 3643.9 km^2 of the total area (24086.59 km^2) representing 15.13% of the total area, Swamp Forest/Riparian covers 4660.33 km^2 representing 19.35% of the total area, Settlement/Bare Ground of the state covers a spatial extent of 7942.95 km^2 covering 32.98% of total area, Degraded Forest covers an area of 3586.26 km^2 representing 14.89%, Waterbodies covers a spatial extent of 741.02 km^2 representing 3.08% of the total area while land use/cover categories such as Thick Vegetation/Plantation and Mangrove covers a spatial area extent of 486.23 km^2, and 3025.9 km^2 representing 2.02% and 12.56% of the total spatial area respectively. In terms of vulnerability rating, landuse/cover categories such as Settlement/Bare Ground, Waterbodies and Mangrove were rated 3 indicating high vulnerability towards flood vulnerability, Cropland, Swamp Forest/Riparian and Degraded Forest were rated 2 indicating moderate vulnerability while Thick/Vegetation/Plantation was rated 1 indicating low vulnerability.

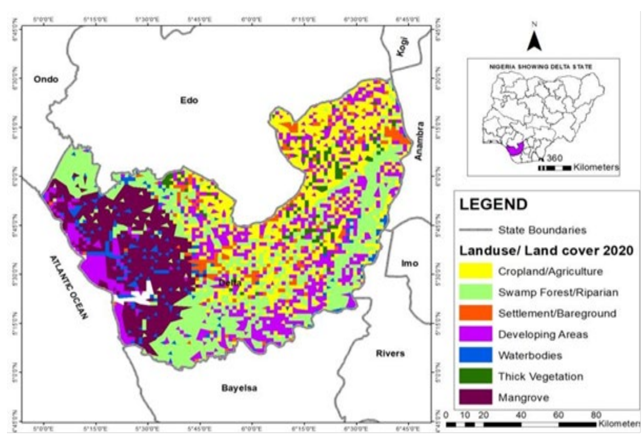

Fig.3. Land use and Land cover Analysis of Delta State

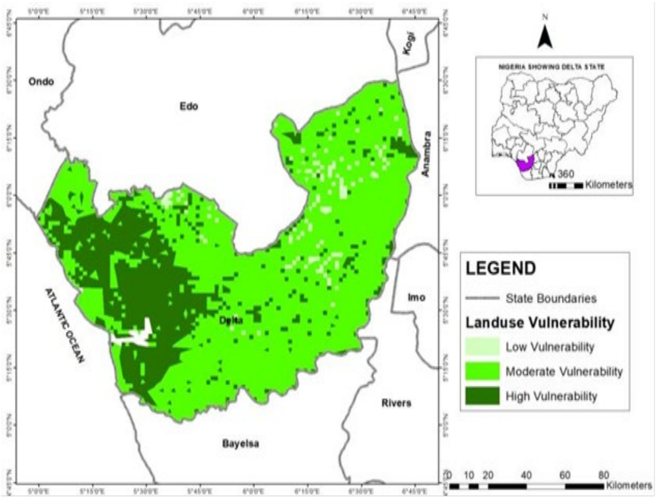

Fig.4. Landuse and Landcover Vulnerability Analysis

Table.2. Land use/Land cover Analysis

Landuse/Land cover	Spatial Extent (km^2)	Percentage (%)	Vulnerability Ratings	Vulnerability Interpretations
Cropland	3643.9	15.13	2	Medium
Swamp Forest/Riparian	4660.33	19.35	2	Medium
Settlements/Bare Ground	7942.95	32.98	3	High
Degraded Forest	3586.26	14.89	2	Medium
Waterbodies	741.02	3.08	3	High
Thick Vegetation/Plantation	486.23	2.02	1	Low
Mangrove	3025.9	12.56	3	High
Total	24086.59	100.00		

Relief Attributes: The relief attributes across Delta state were analysed and presented in Table 3 and Figure 6 and 7. From the analysis, relief level of -19-14m, 14.01-28m and 28.1-58m covers a spatial area of 6068.59 km^2, 6792.21 km^2 and 1478.22 km^2 of the total area of 16626.11 km^2 which represented 36.50%, 40.85% and 8.89% of the total area respectively. The vulnerability rating of relief ranged from -19m to 58m was 3 indicating high vulnerability. The relief level of 58.01-100m, 100.01-140m and 140.01-176m covers a spatial area of 472.87 km^2, 275.55 km^2 and 629.82 km^2 of the total area of 16626.11 km^2 which represented 2.84%, 1.66% and 3.79% of the total area respectively. The vulnerability rating of relief ranged from 58.01m to 176m was 2 indicating moderate/medium vulnerability. The relief level of 176.01-210m, 210.01-243m and 243.01-291m covers a spatial area of 459.53 km^2, 220.4 km^2 and 228.92 km^2 of the total area of 16626.11 km^2 which represented 2.76%, 1.33% and 1.38% of the total area respectively. The vulnerability rating of relief ranged from 176.01m to 291m was 1 indicating low vulnerability.

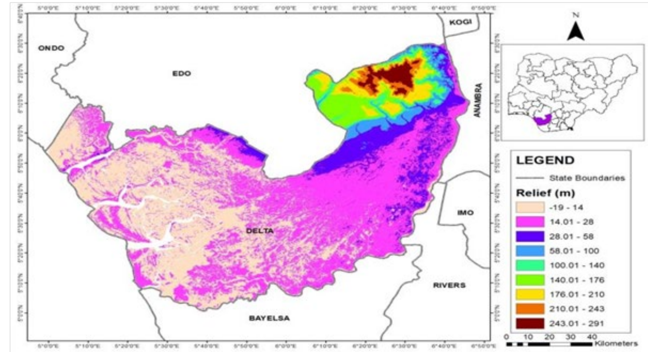

Fig.6. Relief Analysis of Delta State

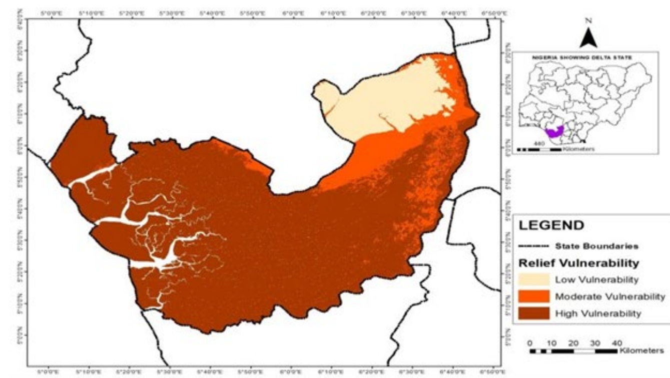

Fig.7. Relief Vulnerability Analysis of Delta State

Table.3. Relief Vulnerability Analysis of Delta State

Relief (9m)	Spatial Coverage (sq km)	Percentage (%)	Vulnerability Levels	Vulnerability Score
-19-14.0	6068.59	36.50	3	High
14.01-28.0	6792.21	40.85	3	High
28.01-58.0	1478.22	8.89	3	High
58.01-100.0	472.87	2.84	2	Moderate
100.01-140.0	275.55	1.66	2	Moderate
140.01-176.0	629.82	3.79	2	Moderate
176.01-210.0	459.53	2.76	1	Low
210.01-243.0	220.4	1.33	1	Low
243.01-291.0	228.92	1.38	1	Low
Total	16626.11	100.00		

Soil Texture Analysis: Soil texture analysis and its vulnerability for Delta state was presented in Table 4 and Figure 8 and 9. From the analysis, three soil textures were identified from the study area which includes coarse, medium texture and fine texture. The coarse soil texture covers spatial area of 7486.67 km^2 of the total area of 16582.64 km^2 representing 45.15% of the total area, the fine texture covers a spatial extent of 3697.93 km2 of the total area representing 22.30% while the medium soil texture covers 5398.04 km^2 representing 32.55% of the total area. The vulnerability rating indicated that coarse soil texture was rated 1, medium texture rated 2 while fine soil texture was rated 3 which indicated low, medium and high vulnerability respectively.

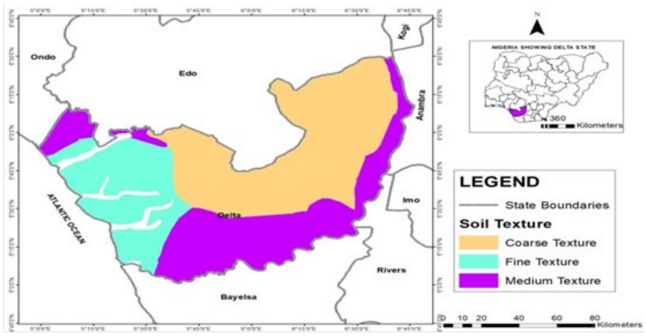

Fig.8. Soil Texture Analysis of Delta State

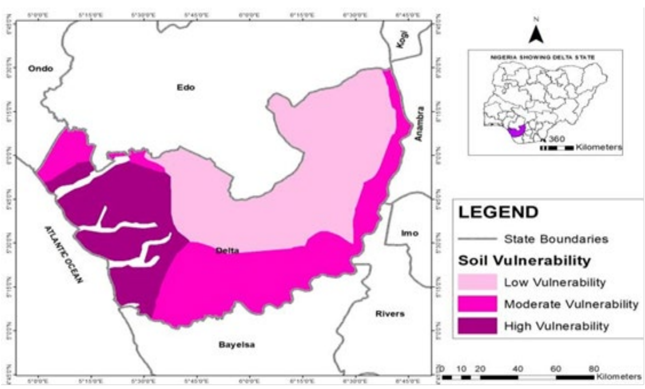

Fig.9. Soil Texture Vulnerability

Table.4. Soil Texture Vulnerability of Delta State

Soil Texture	Spatial Coverage (sq km)	Percentage (%)	Vulnerability Levels	Vulnerability Score
Coarse Texture	7486.67	45.15	1	Low
Fine Texture	3697.93	22.30	3	High
Medium Texture	5398.04	32.55	2	Moderate
Total	16582.64	100.00		

2.2 Flood Vulnerable Levels of the Delta State

The flood vulnerability level of Delta state town/communities was analysed based on the various attributes such as proximity of communities to active river channels, landuse and landcover, relief and soil texture and the outcome was presented in Figure 10 while the classification of the communities into various vulnerability levels was presented in Table 5 and Figure 11. From the analysis, a total of 691 towns/communities was captured and among them, 281 towns/communities indicated low flood vulnerable level representing 40.67% of the total towns/communities, 328 towns/communities indicated moderate flood vulnerable level representing 47.47% of the total towns/communities while 82 towns/communities indicated high flood vulnerable level representing 11.87% of the total towns/communities.

The established levels were categorized into low, medium and high vulnerability and the 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. (2022) established the vulnerability categories of communities in Isoko North LGAs low, medium and high vulnerability. Chukwuma et al. (2021) 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 (2015), Orimoogunje et al., 2016 and Umar and Gray (2022). On the Landuse/Landcover, the activities with high vulnerability reported for this study; that is, settlement, waterbodies, rocky land and sandy area are similar to those reported by Onuigbo et al. (2017). Wizor and Week (2020) opined that various anthropogenic activities affect the landuse and landcover of an area and it is capable of increasing the exposure. Among various landuse/landcover categories reported for this study, settlement was rated the highest among the high vulnerability for landuse/landcover. Changes in land use due to urbanization increases 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 (Adeoye, 2012; Pradhan-salike & Pokharel, 2017). The outcome on elevation showed similarity with that of Happy et al. (2014), and Berezie et al. (2019) which was able to establish the vulnerability level due to elevation of their study area.

2.3 Mitigation Measures in the Study Area

The respondents' perception towards mitigation measures available in their community was presented in Table 6. From the study, raising of house foundation (41.1%) remain the major mitigation measures which was adopted due to the family decision (33.0%) for its adoption while respondents perceived the mitigation measure to be effective (52.7%) towards flood event. The respondents are aware of Government mitigation measures in the environment (51.8%) and the common measure was construction of drainage system (36.6%) which was perceived effective (56.3%). Cirella et al. (2019) indicated similar mitigation measures in their study area while Amangabara and Gobo (2010) suggested that the best approach to flood management in Nigeria is one that seeks a balance application of both structural and non-structural measures. According to Ologunorisa (2009), for flood risk mitigation strategies to be effective, there is need for establishment of coastal management zone authority, land-use zoning, legislation, building codes among others.

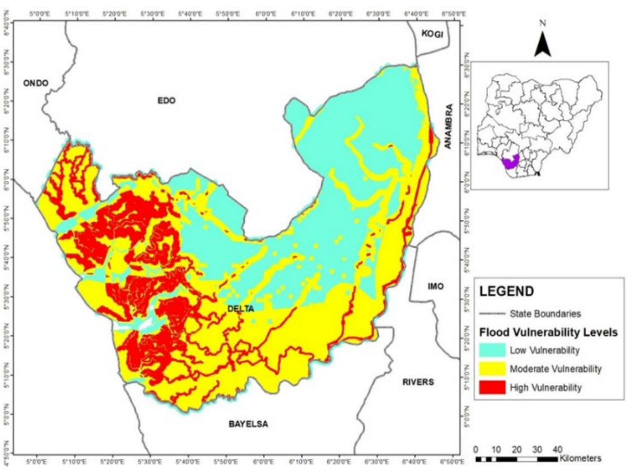

Fig.10. Flood Vulnerable Levels of the Delta State

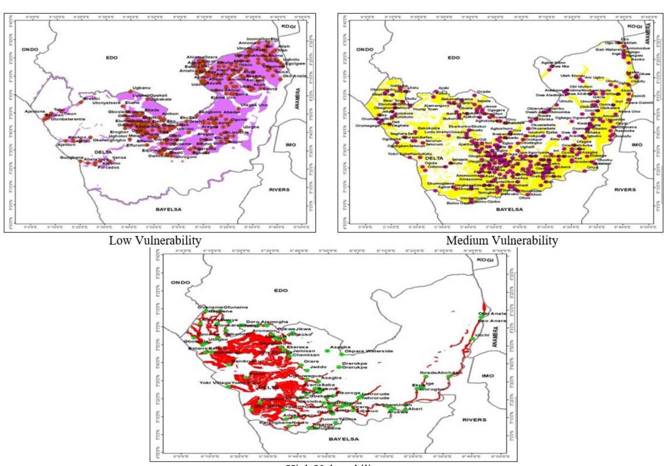

Fig.11. Classification of Flood Vulnerability Levels of Delta State

Table.5. Final Flood Vulnerability Levels

Flood Vulnerability Levels	Number of Towns	Percentage (%)
Low	281	40.67
Moderate	328	47.47
High	82	11.87
Total	691	100.00

Table.6. Mitigation Measures in the Study Area

Variables	N =112	%
Mitigation Measures towards Flood		
Relocation	24	21.4
House foundation raised	46	41.1
Use of sand bags	26	23.2
Wooden bridge construction	10	8.9
Drainage Regular Cleaning	5	4.5
Others	1	0.9
		100
Reason for Adopted Mitigation Strategy		
Cost of production and maintenance	35	31.3
Readily available materials	18	16.1
Based on family decision	37	33.0
Based on community decision	21	18.8
Other	1	.9
		100
Effectiveness of the Mitigation Strategy		
Very Effective	27	24.1
Effective	59	52.7
Less Effective	19	17.0
Ineffective	7	6.3
		100
Aware of Government Mitigation Measures		
Yes	58	51.8
No	6	5.4
Don't Know	48	42.9
		100
Government Mitigation Measures Available		
Early warning system	28	25.0
Construction of drainage	41	36.6
River Channelization	27	24.1
Building dikes around rivers edge	10	8.9
Removal of sand and debris from drainage	6	5.4
		100
Effectiveness of Government Mitigation Measures		
Very Effective	6	5.4
Effective	63	56.3
Less Effective	13	11.6
Ineffective	30	26.8
		100

III. CONCLUSION AND RECOMMENDATIONS

The approach of GIS techniques has further established their usefulness in the establishment of area of interest in flood management study. Through series of physical environment and climate change domains (relief, proximity to active river channels, landuse/land cover, soil texture, elevation and rainfall volume), flood vulnerability of Delta state was established at town/communities' level. In conclusion, all the domains of interest analysed jointly contributed to the vulnerability level of Delta State where 82 (11.87%) of the total communities have high vulnerability level. Various human activities that can contribute to increase vulnerability such as building on river channel should be adequately monitored and prevented. There is need for effective collaboration between the Delta State government and the national, state and local agencies such as NEMA, NIMET, SEMA for development of flood policy plan towards flood disaster management in the state.

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