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Geospatial Analysis of Flood Vulnerability Levels Based on Physical Characteristics and Resilience Capacity of Peri-Urban Settlements in Nigeria

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Abstract

Flooding is becoming a yearly reoccurring event in many communities and cities in Nigeria, leading to the destruction of properties and deaths; hence, we must take measures to either prepare for the impact or curb the occurrence. The study identified flood vulnerability levels of communities in Isoko North LGA based on physical environmental domains such as land use, elevation, and proximity to river channel (drainage) using geospatial techniques. Also, attributes that could contribute to the resilience capacity building of the communities were assessed. From the study, 73.93% of the entire area is moderately and highly vulnerable to flood, while among the communities, seventeen (17) are categorized as moderately vulnerable, and four (4) are lowly vulnerable. The overall resilience capacity of the communities indicated can build a substantial capacity towards community resilience (3.02, 0.06). However, there is a need to encourage collaboration with stakeholders to improve mitigation action and enhance various shortcomings toward resilience capacity building.

Keywords

Community Resilience, Flood Vulnerability, Geospatial Analysis, Physical Environment, Resilience Capacity

1. Introduction

Floods are natural events; however, due to various human-related activities coupled with climate change which is also influenced by human activities, flooding tends to be both human-induced and natural events. As a result, the impact in recent times cannot be over-emphasized, hindering development in many developing countries. According to Sarkar and Mondal (2020), the aftermath of a flood event can be perceived in socio-economic activities, while the extent of such aftermaths is historically increasing globally (Moreno et al., 2020). Flood events can impact various entities both in urban and rural areas, while the extent of the impacts tends to be very high in urban areas (Tamiru & Dinka, 2021). 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 linked to the event between 2019 and 2020, as approximated by the United Nations (Tamiru & Dinka, 2021). Furthermore, floods have caused approximately $280 billion in economic damage in Africa over the past two decades.

In Nigeria, many rural and urban settlements are yearly inundated due to excessive water overflowing their boundary leading to various degrees of socio-economic destruction. Unfortunately, Nigeria has witnessed several flood events over the years with varying degrees of impact, with the flood event of 2012 recognized as the most devastating among many (Tami & Moses, 2015; Nemine, 2015; Ajaero et al., 2016; Eboh et al., 2017; Chigbu et al., 2018; Ezeokoli et al., 2019; Akukwe et al., 2020; Okafor, 2020; Chukwuma et al., 2021). The 2012 flood, according to the National Emergency Management Agency (NEMA), affected 30 of the 36 States of Nigeria, 7 million peopled were affected in these States, 597, 476 houses were destroyed, 2.3 million displaced, and 363 death were reported with a significant track of farmland, and other means of livelihood destroyed, animals and other biodiversity were also gravely impacted upon (Amangabara & Obenade, 2015; Okafor, 2020).

These events and their management established the need to be proactive towards combatting flood events in Nigeria, and the adoption of Geographic Information System (GIS) and Remote System (RS) in the assessment of flood vulnerability is among the leading techniques and can be utilized at various levels. In Nigeria and across the world, GIS and remote sensing techniques have been employed in creating flood vulnerability maps (Ugoyibo et al., 2017; Rimba et al., 2017; Otokiti et al., 2019; Umaru & Adedokun, 2020; Deepak et al., 2020; Chukwuma et al., 2021; Hussain et al., 2021). In addition, Isma'il and Saanyol (2013) noted the efficiency of the techniques in flood management activities due to their capability to establish an area in space that is impacted or possibly impacted by a flood event.

Over the years, GIS and RS technologies have played a significant role in flood risk management at various levels of society, including the coastal areas (Gedam & Dagalo, 2020; Tamiru & Dinka, 2021). Flood risk management entails activities related to flood risk assessment-through, the establishment of vulnerable areas of a location, and flood risk mitigation-establishment of best possible practices to provide early warning, facilitate quick response and minimize the impact of potential flood events (Schanze et al., 2006; Rimba et al., 2017). GIS and RS techniques can achieve several flood risk management activities (Ebert & Kerle, 2008; Panagiota et al., 2011), and the method is efficient in flood vulnerability modeling (mapping), flood risk management planning, and the development of the mechanism of overcoming flood challenges (Otokiti et al., 2019). The present study focuses on the physical vulnerability using various physical-environmental domains such as land use, drainage, and elevation. GIS techniques can spatially process different physical-environmental parameters in flood risk assessment (Danumah et al., 2016; Meena & Gupta, 2017; Njoku et al., 2018; Rimba et al., 2017; Deepak et al., 2020; Tamiru & Dinka, 2021).

Resilience capacities (RC) focus on the possibility of proactive measures to be carried out to combat unwanted events such as floods (Vaughan, 2018). Resilience is the ability of people, households, communities, and institutions to prepare for, respond to, and recover from shocks and stresses. According to USAID (2013), resilience is "the ability of people, households, communities, countries, and systems to mitigate, adapt to and recover from shocks and stresses in a manner that reduces chronic vulnerability and facilitates inclusive growth." Being resilient does not necessarily imply that an entity will maintain its formal state before the undesired event; however, it will support its functionality, although individuals segment of the entity may have adjusted (adapted) to the new environment. A community is said to be resilient when it is capable of demonstrating the ability to withstand an event, self-manage such event before, during, and post-event, and improve on its capacity and experience (Maguire & Cartwright, 2008; Kafle, 2011; Mmom & Aifesehi, 2013). This ability is prompted by resilience capacities, or the sources of resilience that enable protected or improved well-being outcomes. Many practitioners find it useful to organize capacities into three groupings that reflect different dimensions of resilience (Bene et al., 2012):

1) Absorptive Resilience Capacities: The ability to minimize exposure and sensitivity to shocks and stresses through preventative measures and appropriate coping strategies to avoid permanent, negative impacts. For example, disaster risk reduction, financial services, and health insurance.

2) Adaptive Resilience Capacities: The ability to make informed choices and changes in livelihood and other strategies in response to longer-term social, economic and environmental change. For example, income diversification, market information and trade networks.

3) Transformative Resilience Capacities: The governance mechanisms, policies and regulations, cultural and gender norms, community networks, and formal and informal social protection mechanisms that constitute the enabling environment for systemic change. For example, infrastructure, good governance

and formal safety nets.

There is a bit of complexity in the aspect of resilience regarding capacities. For instance, a community could prepare for a particular event through some specific activities; however, if during the event, the prepared activities were not accessible or did not provide the expected outcome, then capacity is not achieved. Therefore, capabilities must be such that they are accessible and functional and give the desired result as regards the undesired events. To be able to "bounce back and transform" community needs series of adequate and efficiency in the areas of communication, emotion, spirituality, and community relationships (Kirmayer et al., 2009). Resilience capacity was integrated into the study to establish a perception of how individuals in flood-prone areas have been resilient to flood events over time.

In Nigeria, there have been several flood risk management studies using GIS techniques at the regional, state, and local level (Mmom & Ayakpo, 2014; Berezi et al., 2019; Wizor & Week, 2020; Atagbaza et al., 2020; Awodumi, 2020; Gift et al., 2020; Okorafor et al., 2021); however, there are limited related studies at the community level. Furthermore, flood risk management should go beyond establishing and developing a vulnerability map of an area; there is a need to mitigate the flood risk of a place effectively. Therefore, understanding the "local" mechanism adopted by local people over the years, which can be improved upon to ensure effective flood risk management is significant for effective flood risk management. The study combined geospatial and quantitative research techniques to assess the flood vulnerability level based on physical-environmental domains and the resilience capacity of peri-urban communities in Nigeria.

2. Method

2.1. Study Area

The study was carried out in Isoko North, a peri-urban settlement in the Isoko region of Delta State, southern Nigeria. Isoko North is one of the Local Government Areas in the Isoko region, the other being Isoko South. The study area is located between latitudes 5˚32'18"N and longitude 6˚12'58"E (**Figure 1**). The climate of the area is the equatorial hot, wet type. The mean yearly precipitation is high, over 2000 mm per annum, and the temperature is between 27˚C - 35˚C. Relative dampness in the region is around 69% - 80%, and daylight of 4.8 bars. There are two seasons in the territory: the dry season (November-March) and the blustery season (April-October).

Delta state was one of the most impacted during the 2012 flood event in Nigeria, with the highest number of communities at risk of flood from river banks overflowing to about 500 m (Amangabara & Obenade, 2015). In addition, several drainage systems criss-cross many of the communities in the state and the communities within Isoko north; thus, 80% of the entire area is prone to flooding due to overflowing rivers banks at the peak of the wet season coupled with that high tides flow of the Atlantic ocean (Ejemeyovwi, 2015). However, limited

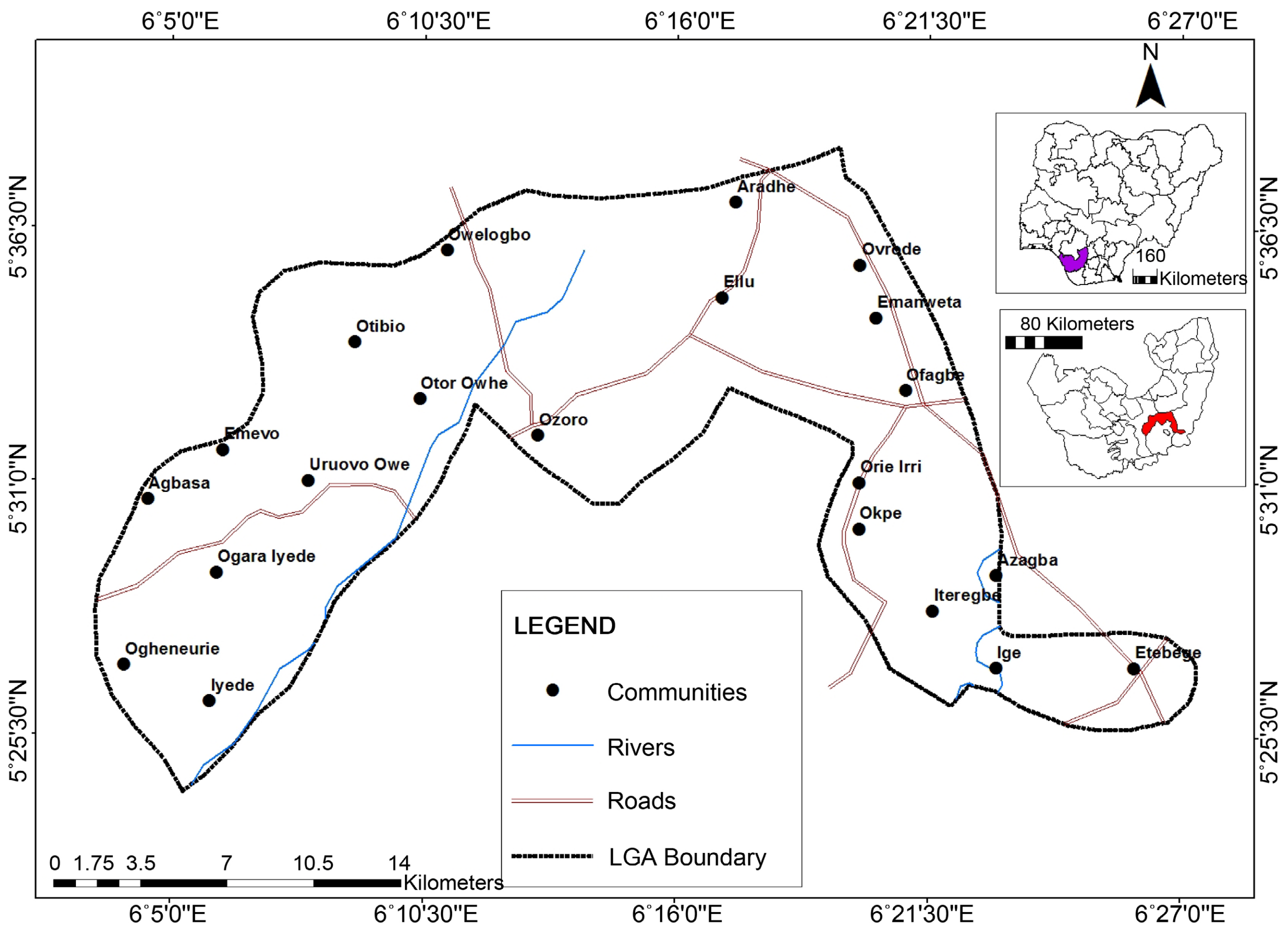

Figure 1. Isoko north LGA showing communities.

studies are available in this locality because flooding has become a yearly event in the area.

2.2. Source of Data

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

The primary data included:

1) Landuse map of Isoko North LGA acquired from the Landsat imagery of 30 m × 30 m.

2) Drainage Network, Road Network, Communities location, and Soil map extracted from the topographic map of 1:100,000 of the study area.

3) Resilience Capacity Assessment Instrument (questionnaire).

The secondary data included:

4) Population data for 2016 of the communities from Isoko North LGA (NPC, 2016).

5) Topographic guide of the investigation zone from Surveyor General's Office, Ministry of Lands and Survey, Delta State.

6) Landsat symbolism of 30 m × 30 m of 2015 got from the US Geological Survey.

2.2.1. Geo-Information and Vulnerability Map Generation

The imagery of Isoko North LGA and the topographical map were geo-referenced to the world coordinate system (WGS 84) in ArcGIS 9.3. From the imagery, the land use map of the study area was acquired, while the drainage network, road network, and communities were imitative from the topographical map. In addition, the soil texture map of Isoko North LGA was also geo-referenced to WGS 84.

Vulnerability Criteria: This study used ranking methods of the vulnerability factors embedded in the Analytical Hierarchy Process (AHP) proposed by Saaty (1980). AHP is a multi-criteria basic leadership method, which gives a methodical way to evaluate and incorporate the effects of different variables, including a few dimensions of reliant or autonomous, subjective just as quantitative data (Bapalu & Sinha, 2006; Berezi et al., 2019). The ranking method was adopted because the criterion weights are usually determined in the consultation process with choice or decision-makers, which resulted in a ratio value assigned to every criterion map (Lawal et al., 2011). In positioning strategy, each measure under thought is positioned at the request of the leader's inclination. To create rule esteems for every assessment unit, the evaluated essentialness weighted each factor for causing the flood.

1) Landuse Map of Isoko North LGA: The geo-referenced Landsat imagery was exported to Idrisi Selva for the generation of the land use map of Isoko North LGA. A supervised classification technique was adopted using the MAXLIKE (Maximum Likelihood Algorithm) module to generate the land use/land cover types in the area. The area is a square kilometre of each land use type that was calculated. The land-use type was converted to vector using Feature to Polygon in the ArcGIS environment. The land use identified was thick vegetation, sparse vegetation, developing area, built-up area and riparian vegetation.

2) Proximity to River Channels (Drainage): The drainage network which determines the proximity to river channels and communities was mapped from the topographical map. These geographic features were digitized and captured as vector data in ArcGIS 10.6.

3) Elevation Map of Isoko North LGA: The elevation map was derived from the height above the mean sea level directly from the Google Earth image. A 10 × 10 grid system covering Isoko North LGA was created in ArcGIS 9.3 and imported into the Google Earth interface. The latitude, longitude, and height in meters at the centre of each grid were recorded and input in Microsoft Excel 2007 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 the interpolation method.

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

1) Reclassification Based on Landuse Types: Four (4) types of terrain were ob-

served concerning their distance to the rivers. In terms of the land use map, the thick vegetation was reclassified to low vulnerability, farmland/sparse vegetation to moderate vulnerability, while built-up areas and water bodies as high vulnerability.

2) Reclassification Based on Drainage Network: In terms of the 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 500 m was regarded as high vulnerability, 1000 m as moderate vulnerability, and 1500 m as low vulnerability (Mmom & Ayakpo, 2014).

3) Reclassification Based on Elevation: The elevation map was also reclassified as follows 1.6 m - 4.6 m to high vulnerability, 4.7 m - 7.6 m to moderate vulnerability, and above 7.7 m to low vulnerability.

The vulnerability levels were assigned values 3, 2, and 1 to high vulnerability, moderate vulnerability, and low vulnerability, respectively, by applying the ranking method to the factors. Using these values, the land use vulnerability map, drainage network vulnerability map, soil texture vulnerability, and elevation vulnerability map were overlaid in ArcGIS 9.3 with the use of the UNION MODULE. The reclassification method was also applied to have the 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 Isoko North LGA, considering the land use, proximity to river channels (drainage network), elevation, and soil texture maps of the area. Finally, a spatial query in ArcGIS 9.3 was used to determine the vulnerability levels each community fell into and the spatial extent of each vulnerability level.

2.2.2. Resilience Capacity Assessment

Research Instrument: In generating perception toward the RCA of the LGA towards flood hazards, a questionnaire was designed using open-closed questions and Likert 5-point scale based on pre-defined domain items (Vaughan, 2018). The main domains of the RCA were adaptive, adoptive and transformative resilience capacity along with fifteen (15) items. The respondents cut across head of households, community-based administrative heads and social workers.

Sample Size: The sample size was estimated using the Cochran formula (Cochran, 1963) in Equation (1):

$$N = \frac{Z^2 \times P \times q}{e^2} \tag{1}$$

where; N = Sample Size, Z = Standard normal deviation corresponding to the level of significance, p = Prevalence of the study population (p = 0.90) from a related study conducted by Pfefferbaum et al. (2014). $q = 1 - p$, e = Minimum error @95% confidence interval.

Given that $e = 0.05$, $p = 0.90$, $z = 1.96$, $q = 1 - 0.90 = 0.1$.

$$N = \frac{1.96^2 \times 0.90 \times 0.1}{0.05^2}$$

$$N = \frac{3.8416 \times 0.90 \times 0.1}{0.0025}$$

$$N = \frac{0.345}{0.0025}$$

$$N = 138$$

For non-response increase by 10%.

=138 + 14

=152

Therefore, a sample size of 150 (respondents) was adopted for the study. Using simple random sampling, ten (10) heads of households were selected from the thirteen (13) wards of the LGA. Also, twenty (20) respondents were purposively sampled which include the community chiefs, administrators from the LGA, and social workers such as teachers and healthcare providers. The total population of the study was 150 respondents.

Data Analysis: The retrieved questionnaire coding was done with MS Excel before being transferred to the Data entry of Statistical Package for Social Sciences (SPSS). Using the SPSS window (Version 22), the analyse tool from the tool menu bar containing the descriptive statistics tools (frequencies, percentages, mean and standard deviation) was adopted for the analysis.

3. Results

3.1. Flood Vulnerability Analysis of Physical Environment Domains

Landuse Vulnerability: The land use map and analysis of Isoko North LGA are presented in Table 1 and Figure 2. The developing land had the highest spatial exten of 27.33%, followed by thick vegetation (27.27%), built-up area (7.10%), and oil palm plantation/farmland/sparse vegetation (18.31%). Thick vegetation was ranked low vulnerability to flood, oil palm plantation/farmland/sparse vegetation was classified as moderate vulnerability, while the built-up area and

Table 1. Landuse/land cover type.

Landuse	Spatial Extent (km^2)	Percentage (%)	Vulnerability Assigned Values	Vulnerability Levels
Flood plain/Wetland/Riparian Vegetation	90.49	19.99	3	High vulnerability
Oil Palm Plantation/Farmland/Sparse Vegetation	82.88	18.31	2	Moderate vulnerability
Thick vegetation	123.44	27.27	1	Low vulnerability
Developing Land	123.72	27.33	2	Moderate vulnerability
Built-Up Area	32.13	7.10	3	High vulnerability
Total	452.66	100.0		

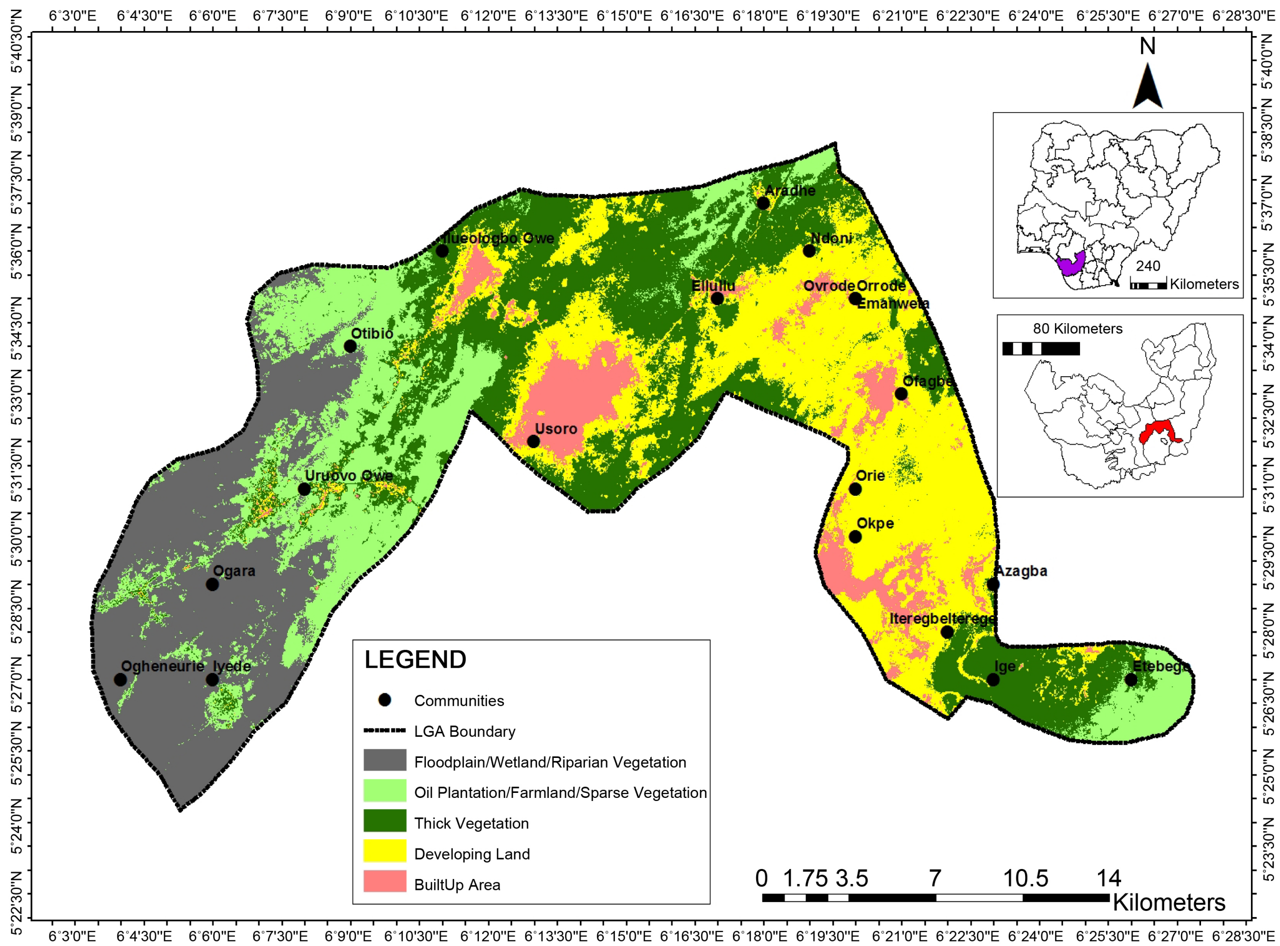

Figure 2. Landuse types of Isoko North.

flood plain/wetland/riparian vegetation were classified as high vulnerability (Figure 3). The analysis thus shows that the spatial extent of the area for low flood vulnerability was 123.44 km^2; moderate flood vulnerability was 206.63 km^2, while high flood vulnerability was 122.62 km^2.

Elevation Vulnerability: The elevation analysis of Isoko North LGA was presented in Table 2 and Figure 4, while the elevation vulnerability was presented in Figure 5. The analysis results show that the elevation was within the range of 12 m and 26 m. The elevation between 12 m and 16 m was ranked high vulnerability, 17 m, and 21 m as moderate vulnerability, while above 21 m was low vulnerability. The spatial extent covered by high vulnerability based on elevation was 112.20 km^2 (25.07%); moderate vulnerability had 300.17 km^2 (67.06%), while low vulnerability had 35.22 km^2 (7.87%).

Proximity to River Channel (Drainage): The drainage network and drainage vulnerability map of Isoko North LGA are presented in Table 3, Figures 6-8. The results showed that the buffer of 500 m from the rivers (high vulnerability) covered a spatial extent of 31.15 km^2; the buffer of 1000 m (moderate vulnerability) covered 26.60 km^2, while the buffer of 1500 m (low vulnerability) covered a spatial extent of 25.64 km^2.

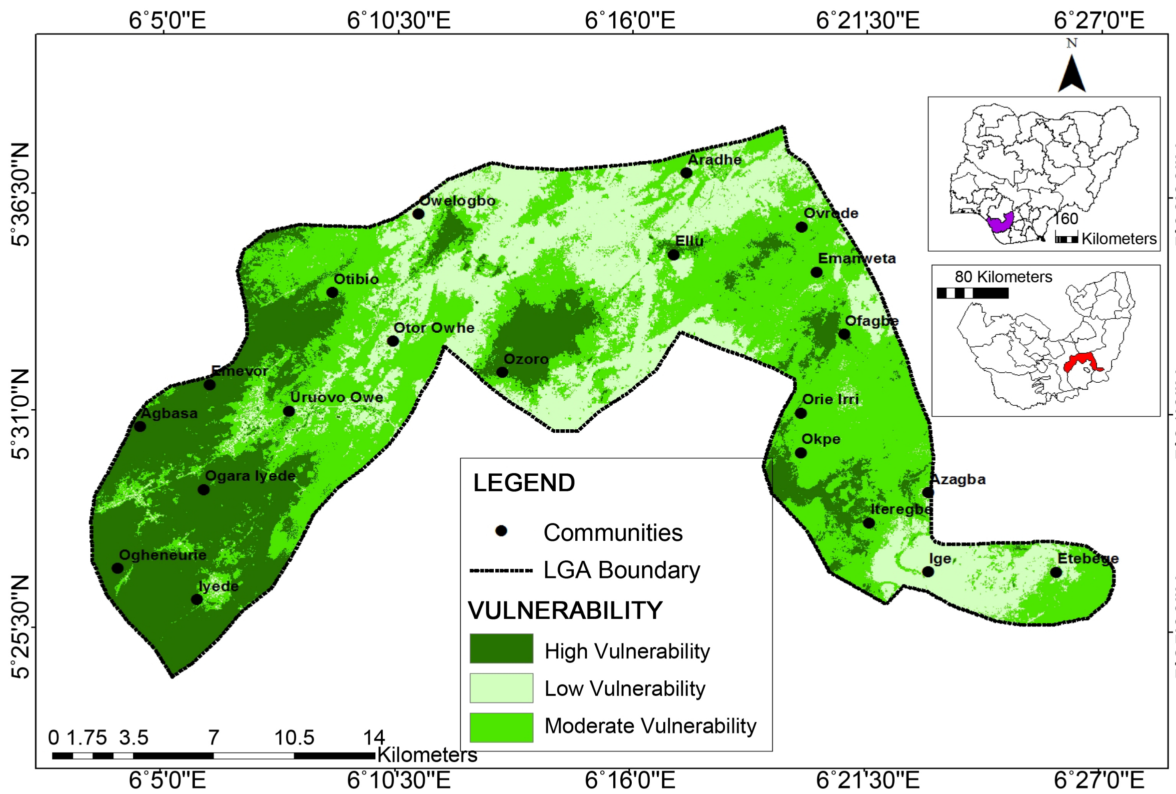

Figure 3. Vulnerability map of Isoko North-based landuse.

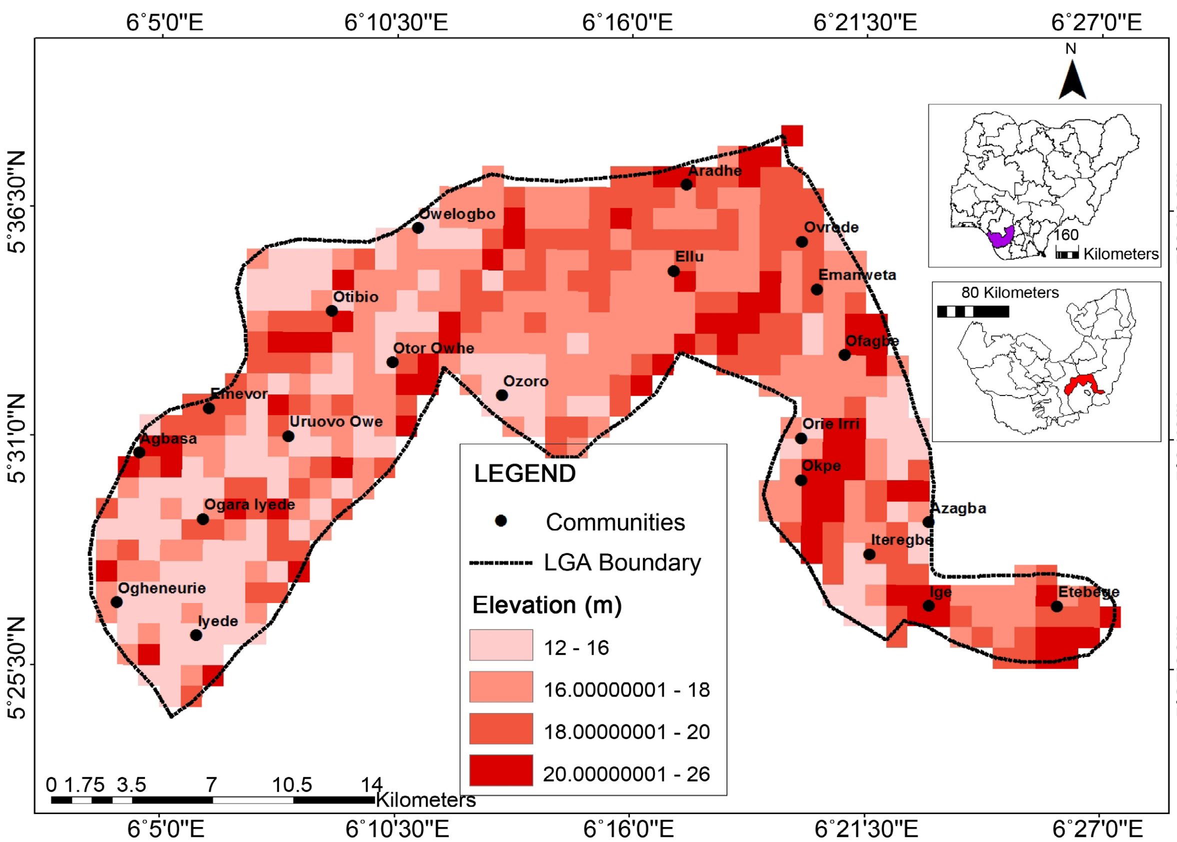

Figure 4. Elevation of Isoko North.

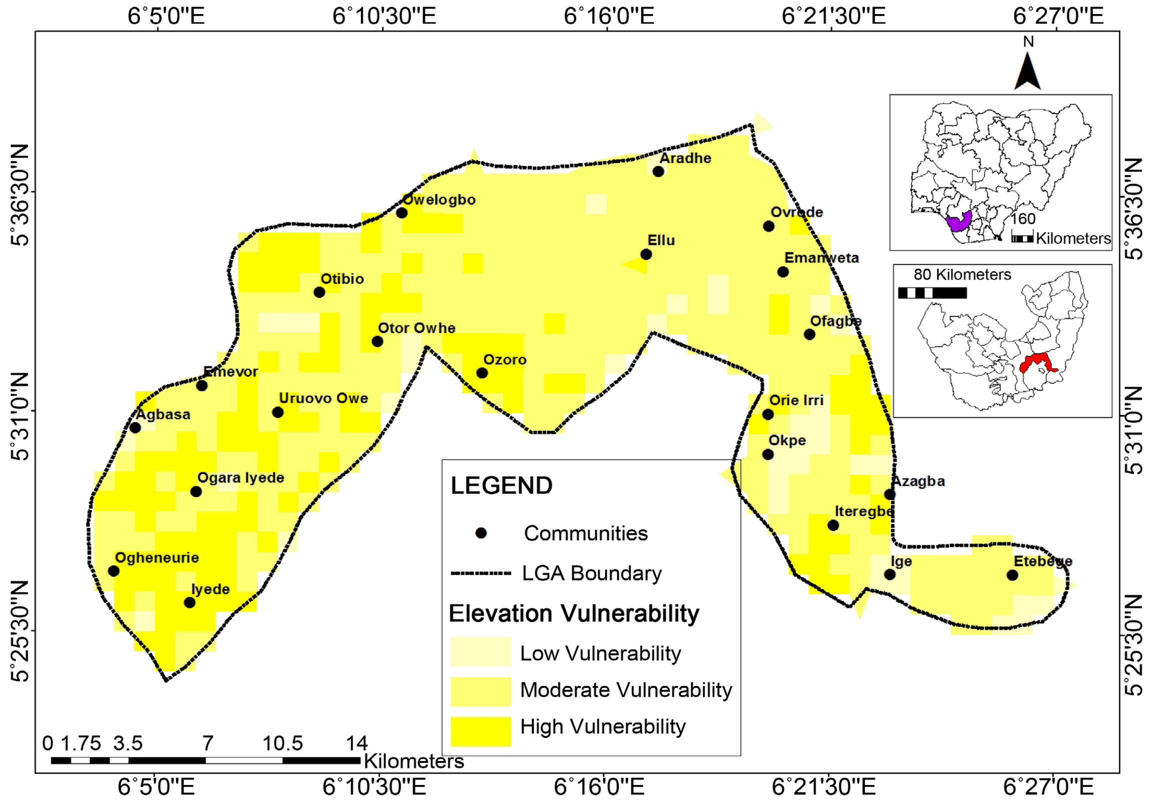

Figure 5. Vulnerability map based on elevation.

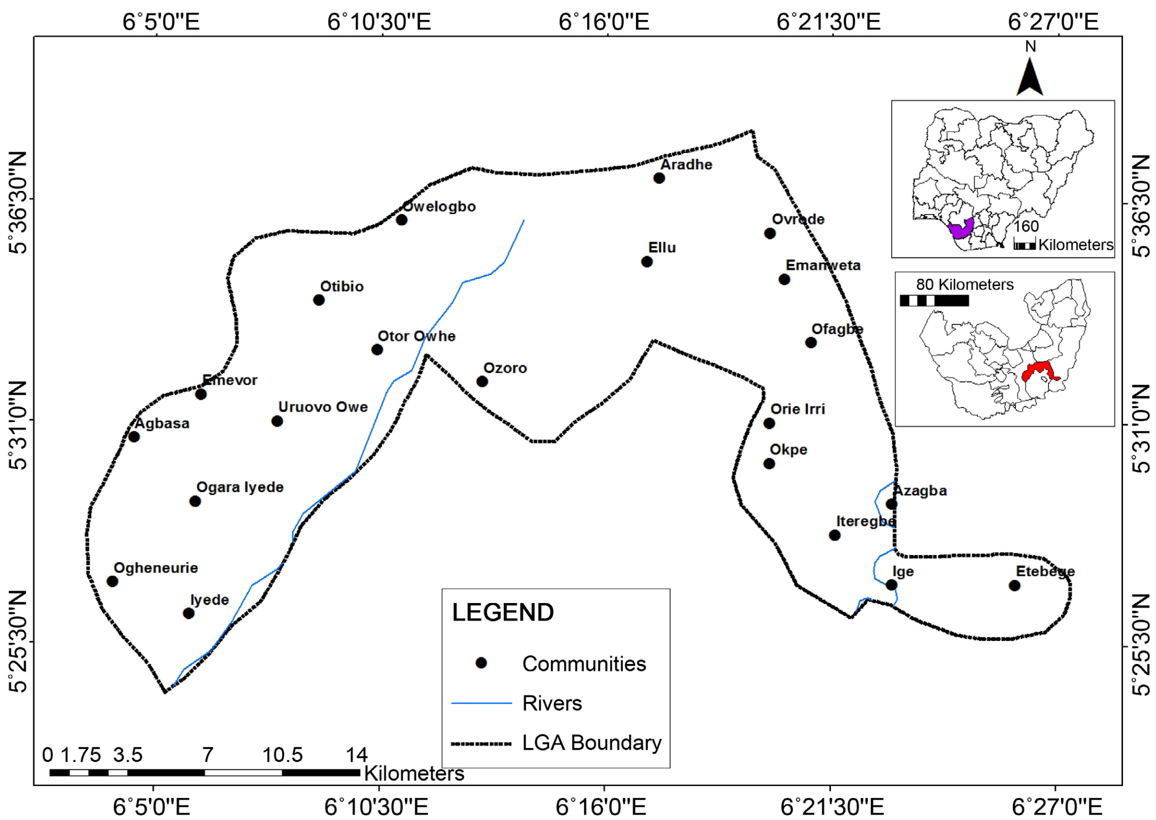

Figure 6. Drainage vulnerability map through buffering analysis in Isoko North LGA.

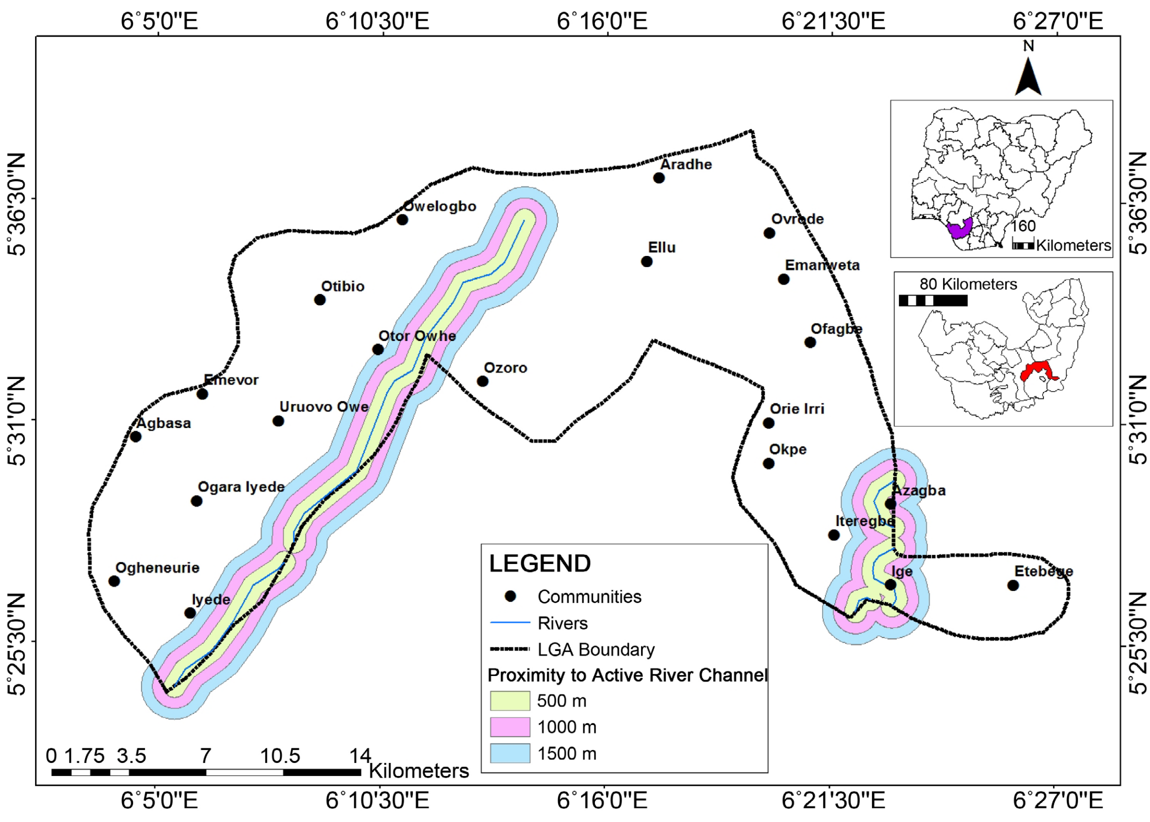

Figure 7. Drainage vulnerability map through buffering analysis in Isoko North LGA.

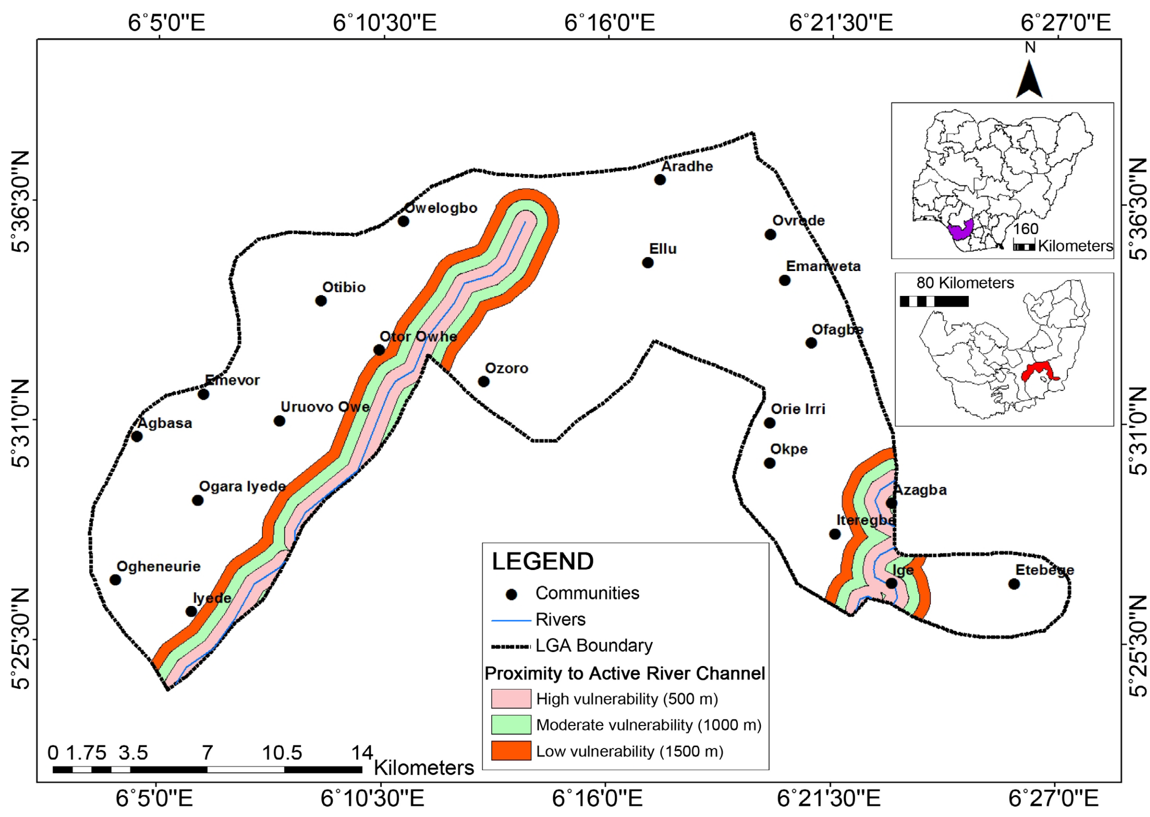

Figure 8. Drainage vulnerability map through buffering analysis in Isoko North LGA.

Table 2. Elevation data of Isoko North LGA.

Elevation (m)	Spatial Extent (km^2)	Percentage (%)	Vulnerability Assigned Values	Vulnerability Levels
12.0 - 16.0	112.20	25.07	3	High vulnerability
17.0 - 21.0	300.17	67.06	2	Moderate vulnerability
22.0 - 26.0	35.22	7.87	1	Low vulnerability
Total	447.59	100.0		

Table 3. Drainage vulnerability of flood in Isoko North LGA.

Buffer Scenarios (m)	Spatial Coverage (km^2)	Percentage (%)	Vulnerability Assigned Values	Vulnerability Levels
0 - 500	31.15	37.35	3	High vulnerability
501 - 1000	26.60	31.90	2	Moderate vulnerability
1000 - 1500	25.64	30.75	1	Low vulnerability
Total	**83.39**	**100.0**		

Flood Vulnerability Map and Communities: The analysis of the flood vulnerability map of Isoko North LGA is presented in Table 4 and Figure 9. The analysis shows that the low vulnerability areas covered a spatial extent of 121.72 km^2 (34.0%), while moderate vulnerability areas covered 317.19 km^2 (45.4%). In a related development, the high vulnerability areas covered a spatial extent of 27.90 km^2 (18.5%).

The communities in Isoko North LGA were classified to flood vulnerability levels based on elevation, land use, and proximity to active channels. Thus, the vulnerability level of each major community is presented in Table 5 and Figure 10. The analysis showed that no major community in Isoko North LGA was highly vulnerable to flood. However, communities such as Owelogbo, Etebege, Aradhe, and Agbasa were lowly vulnerable, and Ozoro, Uruovo Owe, Ovrode, Otibio, Orie Irri, Okpe, Ogeneurie, Ogara Iyede, Ofagbe, Iyede, Iteregbe, Ige, Emanweta, Ellu, Azagba, Emevor and Otor Owhe were moderately vulnerable.

3.2. Resilience Capacity Assessment (RCA)

From the analysis, most of the engaged respondents were Male (87, 58%) within the age range of 30 - 40 years (51, 34%). These respondents confirmed that they are married (87, 58%) with a primary level of education (62, 41.3%) while there are primary occupation is classified as self-employed/trading/commerce (67, 44.7%) as highlighted in Table 6. The resilience capacity of Isoko North LGA was assessed based on Absorptive, adaptive, and transformative indices (15) as presented in Table 7. Among the absorptive capacity, the highest index indicated that "households get and give help to people within their community"

Table 4. Flood vulnerability levels in Isoko North LGA.

S/N	Spatial Extent (km^2)	Percentage (%)	Vulnerability
1	121.72	26.07	Low vulnerability
2	317.19	67.95	Moderate vulnerability
3	27.90	5.98	High vulnerability
Total	**466.81**	**100.0**	

Table 5. Flood vulnerability of communities in Isoko North LGA.

Low Vulnerability	Moderate Vulnerability	High Vulnerability	Total
	Ozoro, Uruovo Owe, Ovrode, Otibio, Orie Irri, Okpe, Ogheneurie, Ogara, Iyede, Ofagbe, Iyede, Iteregbe, Ige, Emanweta Ellu, Azagba, Emevor, Otor Owhe	Owelogbo, Etebege, Aradhe, Agbasa	21
0	17	4	21
0.0	80.95	19.05	100.0

(3.65, 1.01). In contrast, the lowest revealed that "households receive emergency food or cash assistance from the government or NGO during shock event such as flooding" (2.14, 1.09). For the adaptive capacity, the highest index indicated that "household network with other households to achieve various services needed in the community" (3.71, 1.02), while the lowest indicated that "households in the community have access to necessary information and easily adopt improved practices" (2.34, 1.02). The transformative capacity showed that the "market available for the household to sell and buy agricultural products" has the highest index (3.65, 1.09) and the lowest index was "local government responded to community requests for improving community assets or services" (2.04, 1.08). Overall, the assessment indicated that the community has excellent resilience capacity, which could improve (3.02, 0.06).

4. Discussion of Findings

The GIS-based analysis of various physical environmental domains such as land use, elevation, and proximity to river channel (drainage) was able to highlight vulnerability levels of communities in Isoko North LGA of Delta State, Nigeria. The built-up area was regarded as a high vulnerability because the presence of hard surfaces can prevent easy infiltration and thereby enhance higher runoff which can easily cause flood (Berezi et al., 2019). The connection between built-up areas and floodplain/wetland/riparian vegetation can be influenced by urbanization leading to the reclamation of sensitive land areas such as flood plains. Places such as Ozoro, which represents the Administrative Headquarters of the LGA, showed a major built-up area; hence, highly vulnerable due to

Table 6. Socio-demographic details of the respondents.

Variable	Frequency (n = 150)	Percentage (%)
Sex of Respondents		
Male	87	58
Female	63	42
Age (years)		
18 - 29 years	29	19.3
30 - 40 years	51	34
41 - 50 years	35	23.3
51 - 60 years	25	16.7
61 and above	10	6.7
Marital Status		
Single	26	17.3
Married	87	58
Divorced	10	6.7
Widowed	12	8
Separated	15	10
Educational Qualification		
No Formal Education	42	28
Primary	62	41.3
Secondary	30	20
Tertiary	16	10.7
Primary Occupation		
Unemployed	23	15.3
Professional Occupation	19	12.7
Skilled/Managerial Occupation	27	18
Manual/Partly Skilled	9	6
Self-employed/Trading/Commerce	67	44.7
Others	5	3.3

changes in land use/cover. Studies have confirmed various flooding events in this area (Anie, 2010; Iroaganachi & Ufere, 2013; Amangabara & Obenade, 2015). The flood vulnerability of the Niger Delta region has been connected to elevation characteristics by several studies (Happy et al., 2014; Berezi et al., 2019), which is reflected from Isoko North's point of view. Places like Iyede, Ige, Okpe, and Ozoro are among the highly vulnerable areas due to elevation characteristics.

Delta state as a whole is highly crisscrossed with several rivers and drainage systems that are empty to the Atlantic Ocean (Amangabara & Obenade, 2015),

Table 7. Resilience capacity assessment of Isoko North LGA.

Resilience Capacity Assessment	A (%)	D (%)	Mean (SD)
Absorptive Capacity Index			
1) Households have access to an informal safety net (e.g., Religious and saving groups) in the community	57.3	12.6	3.61 (1.18)
2) Households get and give help to people WITHIN their community	58.7	8.6	3.65 (1.01)
3) Households have access to their saving during shock events such as flooding	49.3	10.0	3.61 (0.98)
4) There is a government and/or NGO disaster planning and/or response program in the village	29.1	53.4	2.51 (1.45)
5) Households receive emergency food or cash assistance from the government or NGO during shock events such as flooding	37.2	51.7	2.14 (1.09)
			3.10 (0.72)
Adaptive Capacity Index			
6) Households show aspirations, confidence to adapt, and a sense of control over their life	58.0	9.3	3.52 (1.00)
7) Households get and give help to people OUTSIDE their community	43.3	45.0	2.98 (1.43)
8) Households network with other households to achieve various services needed in the community	54.7	9.3	3.71 (1.02)
9) Adults in the household are educated and engaged in various forms of socio-economic activities	40.1	48.2	2.42 (1.12)
10) Households in the community have access to necessary information and easily adopt improved practices	32.0	49.4	2.34 (1.02)
			2.99 (0.62)
Transformative Capacity Index			
11) Households have access to a formal safety net (e.g., food assistance, shelter, and government/NGO assistant) in the community	24.6	55.4	2.63 (1.24)
12) Market available for households to sell and buy agricultural products	55.4	12	3.65 (1.09)
13) Households have access to essential services (e.g., Roads, Schools, Healthcare, Police) in the community	46.6	21.3	3.35 (1.24)
14) Local government responded to community requests for improving community assets or services	30.4	43.3	2.04 (1.08)
15) Households participate in the decision-making process that concerns the community	42.7	18.0	3.32 (1.08)
			2.99 (0.65)
Overall Resilience Capacity			**3.02 (0.06)**

*Key: A-Agreed (Strongly Agreed + Agreed), D-Disagreed (Strongly Disagreed + Disagreed), SD = Standard Deviation.

while the entire area is about 20 mm above sea level (Ejemeyovwi, 2015). In Isoko North, rivers such as Iyede, Ariola and Ase run through communities such Iyede, Otor Owe, Ige, Iteregbe, and Azagba, which influence the flood vulnerability of the communities. The areas with moderate and high vulnerabilities covered 73.93% of the entire area of Isoko North LGA, which means the majority of

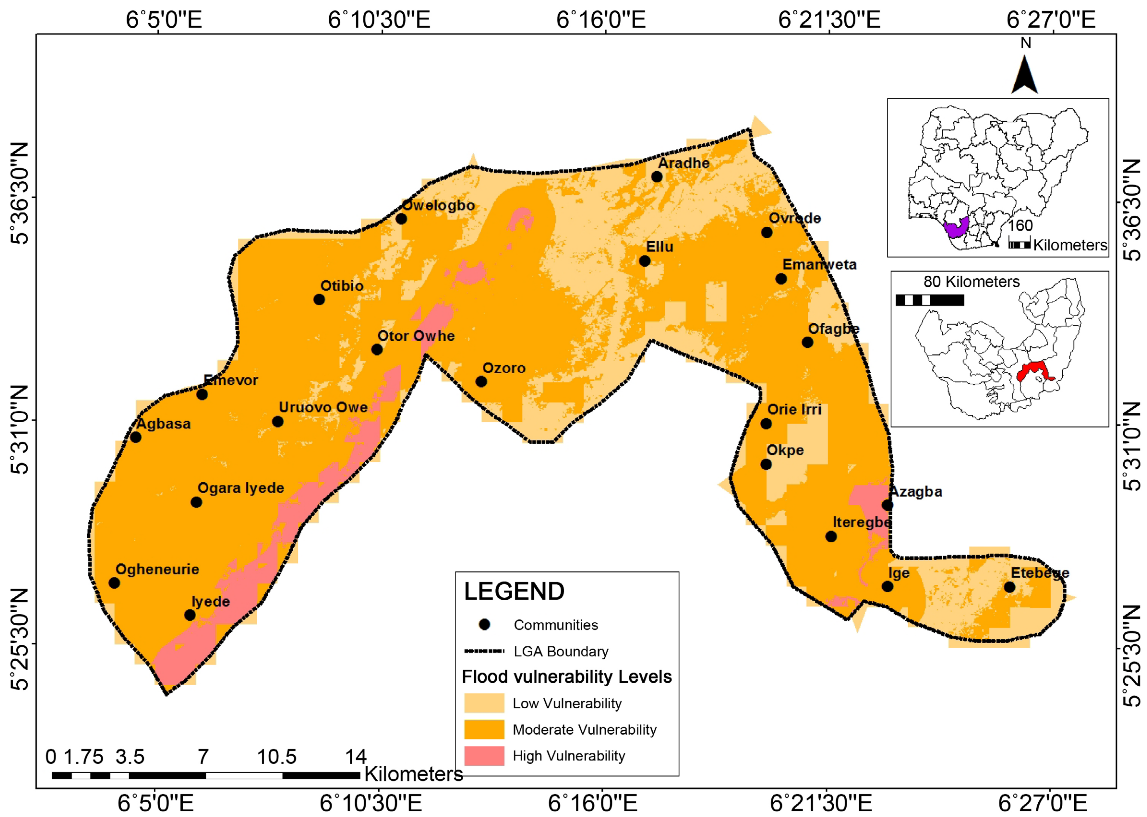

Figure 9. Flood vulnerability map of Isoko North LGA.

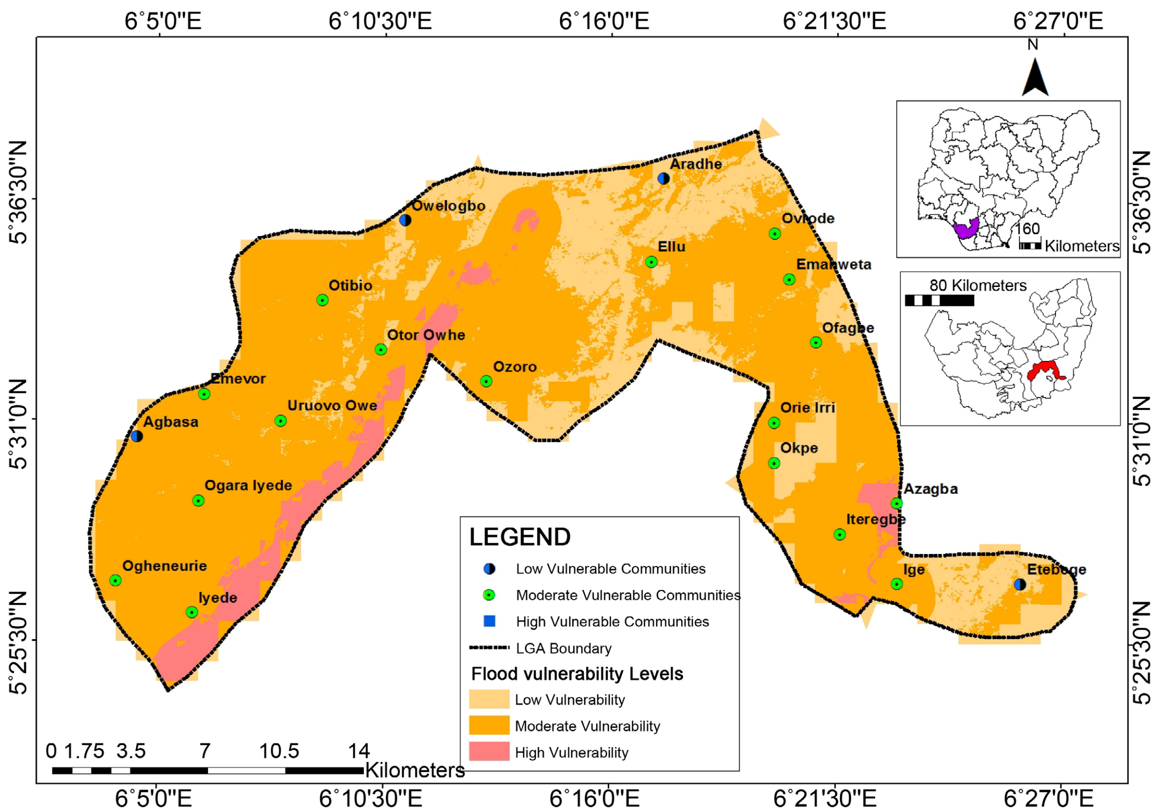

Figure 10. Flood vulnerability levels of communities in Isoko North LGA.

the area was prone to flooding, considering the land use, elevation, and proximity to an active river network. Thus, 17 making 80.95%, were moderately vulnerable while only 4 (19.05%) were lowlily vulnerable to flood in Isoko North LGA.

Bodland and Granberg (2018) noted that mitigating community vulnerability requires public engagement towards improving adaptive capacity. What is made evident from the study is the need for community resilience built based on community capacity, participation, social capacity, economic development, information, and communication. These cut across the three RCAs measured in this study. From the survey, the households reveal social connectivity/networking, capacity, and economic development attributes. This indicates aboriginality among the individual from the communities, which can help build community resilience. This is in line with Usher et al. (2021) and Pfefferbaum et al. (2013), who noted community connectivity as part of the basis for developing community resilience (that is, the capability of community members to intentionally take deliberate, goal-oriented, and cooperative actions to assuage from destructive impacts of unwanted events such as disasters).

5. Conclusion

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 study concluded that domains of interest jointly contributed to the vulnerability level of Isoko North LGA communities, and based on this, seventeen (17) communities were noted to be moderately vulnerable while four (4) communities have low vulnerability. Also, the communities showed promising capacities towards various RCA indices that can spurn a better building process for community resilience, hence, the need for collaboration with external bodies (government and non-government organizations) to enhance various shortcomings. Communities are not only vulnerable to physical environment, social and economic status are also a contributing factor and these must be included in the overall assessment of a community. Also, improving resilience requires technical, and practical knowledge and most importantly, contribution from the targeted community or organization. Therefore, future studies should consider various vulnerability aspects combined with resilience assessment.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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