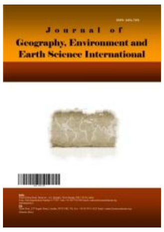

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Flood Vulnerability Assessment on Selected Communities in Ikwerre Local Government Area of Rivers State, Nigeria, Using Remote Sensing and GIS Techniques

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Authors' contributions

This work was carried out in collaboration among all authors. Author EW and POPE designed the study, MA, CHW and OOA collected data and perform spatial analysis. Authors EW, ICE and LCBA make corrections on the final draft. Author EW and OOA managed the literature review. All authors read and approved the final manuscript.

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ABSTRACT

A flood is an overflow of water that submerges land that is usually dry. Flooding may occur as an overflow of water from water bodies, such as river, lake or ocean, in which the water overtops or breaks levees, resulting in some of that water escaping its usual boundaries, or it may occur due to

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an accumulation of rain water on saturated ground in an area. To find out the most vulnerable communities, the Digital Elevation Model (DEM) and location data of selected communities were used. The Image Re-class and Map Overlay were performed on QGIS software to identify communities that are most affected. The result shows that the region has no river channel that discharge excess water easily. It also shows that four, out of twelve settlements were located at the high risk zone. The settlements are Uniport, Omuoda, Omuahunwo and Okparagwa. It was recommended that the high risk zone in the area should be provided with artificial water channel that will contain and convey surface sun-off to a nearby stream. The local authority should relocate the affected settlements to a safer zone.

Keywords: Flooding; Ikwerre; Vulnerability; DEM; GIS; remote sensing, Settlement.

1. INTRODUCTION

Floods are among the most devastating natural hazards in the world, claiming more lives and causing more property damage than any other natural phenomena [1-7]. Floods are one of the greatest challenges to weather prediction [8] [9]. Flooding is an overflow of a body of water that inundates land. This usually occurs due to the volume of water within a body of water, such as a lake or river, exceeding the total capacity of the body, resulting in some water flowing outside of the normal boundaries of the body. It can also occur in rivers. When the strength of the river is so high, it flows right out of the river channel. Flooding is an anticipated hazard in the coastal regions and when it occurs, it leaves loss and damage at its wake giving rise to disasters. The need for investing and mitigate measures can never be over-emphasized as the presence and adherence to control measures, both structural and non-structural is key in avoiding loss and damage of properties [10] Floods are part of the Earth's natural hydrologic cycle. Sometimes the hydrologic cycle got out of balance, sending more water to an area than it can normally handle. The result is a flood [11]. Cases of flooding in Nigeria have been frequently reported particularly in the wet season. This phenomenon mainly affects places within the floodplain of the major rivers and their tributaries as usually been predicted by the Nigeria Meteorological Agency (NiMet). For example, in the year 2020, NiMet predicted that heavy rainfall may result in flooding, which could disrupt traffic, delay construction activities, and weaken or wash out the soil and culverts that support roads, tunnels, and bridges. The riverine flooding mostly occurs at the lower altitude around waterways as described by De Risi *et al.,* [12].

According to Flood list Africa, the NiMet 2021 flood prediction becomes true due to the fact that most of the states mentioned have now witness different magnitude of flooding. The states that witness the flooding between July and August, 2021 include Lagos, Bauci, Kano, Jigawa, Kebbi, Sokoto, Rivers, Cross River, Akwa Ibom, Anambra, Ebonyi, Enugu, Ekiti, Oyo and Osun.

Flood events and impacts in recent times have arguably been unprecedented and affected the lives of hundreds of millions of people across the world. These impacts have been shared by both developed and developing countries (DCs) with rapid urban expansion taking place in many flood-prone areas. Concerns for flooding and the associated human impacts are clearly of global significance, especially when allied with the fears of climatic change and associated changes in rainfall events and sea level rise [13]. The rapidly growing urban environments in many areas correspond with a lack of urban planning strategies, the deterioration and lack of capacity of urban drainage infrastructure and an increased rate of development on floodplains [14-15]. Additionally, the increasing densities of populations (particularly in the urban areas of most DCs such as Nigeria), alongside the poor level of awareness and the limited efforts of many stakeholders towards flood risk reduction are critical issues undermining possible efforts towards addressing the hazard [16-18]. According to Umeuduji [19] flood are naturally events which mainly happen when catchments receive unusually high amount of water, say from rainfall or snowmelt depending on the environment.

1.1 Causes of Flooding

Over the past 2 decades, the causes of flooding in Nigeria have received significant attention in the literature [20] [16] [21-26]. Debates arising from the literature indicate that Port-Harcourt, Lagos as well as other states, floods are mainly the consequences of climate-change-induced short-duration high-intensity or long-duration-low-intensity rainfall [27]. This is unsurprising considering that climate change has arguably influenced regional precipitation patterns in recent history. Odjugo [28], concluded that there are now more high-intensity short-duration rainfall events and more low-intensity long-duration rainfall events than there were 3 years ago. Other factors have also been investigated with reference to the causes of these floods in Port Harcourt and Lagos. These include the topography of the area, land use (LU) and land cover (LC) modifications, and influence of canals, lagoons, and beaches [23] [29-30]. Other factors considered are urbanization and population growth, poor urban planning, and poor environmental management and the indiscriminate disposal of solid waste [31] [21]. It is also suggested that tidal and co-tidal influences and frequent incursion from the Atlantic into the lowlands during heavy storms also play important roles [32].

Umeuduji [19] postulate that under normal circumstances, ocean currents usually wash the coastlines, but some violent disturbances (such as earthquakes or vulcanicity) in the ocean can generate devastating tsunamis or hurricanes that can hit and flood the coastal environment. Also, when precipitation proceeds at a rate that exceeds infiltration and surface evacuation, water will automatically accumulate on the land surface hence leading to flooding .In several continental plains or area with less pronounced slopes excessive rainfall has always generated flooding. Abdullahi *et al*., [33] reported that flood of 2012 is a major environmental event in Nigeria since its independence. The floods began in early July, killed 137 people and displaced over 120,000 people nationwide [34] [33]. Similarly, the 2013 report of 2012 flooding stated that Floods are the most common and recurring disaster in Nigeria. The frequency, severity, and spread of these floods are increasing. Beginning in July 2012, heavy rains struck the entire country. The impact of the 2012 flooding was very high in terms of human, material, and production loss, with 363 people killed, 5,851 injured, 3,891,314 affected, and 3,871,53 displaced [35]. According to Nigeria's National Emergency Management Agency (NEMA), nearly half a million people have been affected by 2018 flooding in 8 states of the country. At least 108 people have died in the flooding, with a further 192 injured. The affected states include Anambra (64,331 people affected), Benue (2,201), Delta (37,017), Edo (31,113), Kebbi (94,991), Kogi (118, 199), Kwara (41,680) and Niger (51,719) [36] [33].

1.2 Frequency of the Occurrence and Impacts

Flooding and flood risk management are issues of grave significance in Port Harcourt and Lagos [23, 29]. It is clear from previous studies [25] [37] [22], that flooding in the area can be devastating, affecting hundreds of thousands of people and causing considerable economic damage. A typical example is the July 2012 flooding event, which affected approximately 5 thousand people and resulted in about 25 deaths. The direct economic losses resulting from the event total led about 50 billion Nigerian naira (i.e. USD 250 million). Public utilities including road networks, bridges, and schools were destroyed. In addition, houses collapsed, private homes were submerged, and several cars were swept away by flood water [38] [39].

These factors global climate change, poor urban planning, urbanization anthropogenic activities, seem to influence the occurrence of the hazard and the exposure of elements at risk. However, in relation to the vulnerabilities of social systems to flooding in the area, the development of slum settlements and poor perception of flooding among local communities, urban residents and the general public are critical factors [40] [41] [20] [30] [42] [43].

To date, flooding is characterized by severe consequences, high raise concerns about a lack of early warning and evacuation systems. Impacts from flooding compounded by population density and the upward trends of urban growth in the area [29]. Also, flood water depth, inundation extent and duration as well as water flow velocity play contributory roles. The general impacts (such as displacement from homes, mortality, physical injuries, disruption of economic activities, destruction of urban infrastructure, and submergence of buildings) that relate to social systems directly have been extensively considered in the literature [44] [45] [29] [46]. However, there are reports that Lagos flooding causes severe additional impacts including the loss of social values, spread of vector-borne diseases, as well as air and water pollution [47] [46] [48].

1.3 Flood Hazard

In terms of both magnitude and severity of floods, resulting hazards or effects have been broadly classified as primary, secondary, tertiary or long –term. Primary are physical structures set up by man, secondary aspect are disruptive effects of flooding on human settlements and economic activities, and the tertiary impacts are graded into time.

Olajuyigbe*et al.,* [46] report that flood hazard increases city-wide poverty as a result of the farmlands which are destroyed and essential services which are often interrupted. Adelekan [47,48] investigated these impacts using four poor urban communities in Lagos as case studies and identified three significant scales: individual, household, and community. At the individual scale, the reluctance of friends and family to visit one another while in flooded houses affects social relationships. This has broad adverse implications on community lifestyle and further compounds depression among flood victims in Lagos. Food insecurity is equally an important issue at this scale as food items stored in individual homes are often lost during flooding. In addition, there can be numerous health impacts including chronic skin infections from exposure to contaminated environmental systems and increased effects on those with an already poor health history.

Household and community scales of impacts are mainly indicated by the secondary effects of flooding in Lagos. Household impacts include deterioration of building quality, intrusion of contaminated water into apartments, lack of good drinking water, and loss or damage to household properties including sanitation facilities. The community impacts include an unclean environment, disruption of movement, and damage to public utilities. Urgent needs arise where community schools were flooded and schooling for children has been interrupted. This is an important issue within the context of human development. In many other DCs where it is also applicable, community leaders and the local authorities have often instigated measures to ensure that children's schooling is not interrupted despite the magnitude of flooding. In Bangladesh for example, a strategy known as "floating schools" in which classrooms are constructed on boats is being put in place during flooding [49]. This enables provision of uninterrupted education for children who have been impacted and whose education has been disrupted by flood catastrophes.

1.4 Climate Change and Flooding

According to United States Environmental Protection Agency, Climate change may cause river floods to become larger or more frequent than they used to be in some places, yet become smaller and less frequent in other places. As warmer temperatures cause more water to evaporate from the land and oceans, changes in the size and frequency of heavy precipitation events may in turn affect the size and frequency of river flooding. The Quartz Africa reported that the first factor aggravating flooding is climate change, which has been shown to contribute to more extreme storms and rainfall. Another factor contributing to flooding in cities is that Nigeria has experienced rapid urban growth and planning is poor. Similarly, Agbonkhese *et al.,* [50] confirmed that climate change, coupled with other factors have been traced to be the causes flood in Nigeria. Other factors include poor planning, poor governance, poor drainage facilities, lack of proper environmental planning and management strategies, among others.

1.5 Use of Geographic Information System in Monitoring Floods

Finlayson, 2016 defined vulnerability as "the degree to which a flood is sensitive to and unable to adapt to or moderate the consequences of climate change and other (anthropocentric) pressures on its ecological character" and comprised two major components, namely the sensitivity of the system and its adaptive capacity or resilience. Sensitivity was defined as "the degree to which a flood is affected, either adversely or beneficially, by climate-related stimuli" and adaptive capacity as "the ability of a flood to adjust to climate change, to take advantage of opportunities, or to cope with or moderate the consequences." By bringing together various methods and approaches, a general framework for flood vulnerability assessment was developed, comprising the following elements:

(i) Establishing the status of the biophysical and social components of the flood, including present and recent pressures;
(ii) Determining the sensitivity and adaptive capacity of the ecological and social components of the flood to multiple

pressures and developing plausible futures;

(iii) developing responses to ensure these future can be achieved; and

(iv) Monitoring and adaptive management to reach the desired outcomes.

Obtaining the necessary information to undertake an effective assessment may not be straightforward given the paucity of spatial and temporal data, at appropriate scales, as a time series to determine the present condition and trends in the condition of a flood and its sensitivity and adaptive capacity. It is expected that in many instances the assessment will be an iterative process based on qualitative or subjective information and updated or improved as more information becomes available [51-52].

Therefore, monitoring of the flood system in the areas vulnerable to flood and also to provide flood vulnerability map in the metropolis has become very vital to the socio-economic development of the region and in doing this, Geographic Information System (GIS) is believed to be very important in generating such maps through rigorous spatial analysis [53-54] viewed GIS as a tool for storing, manipulating and displaying large quantities of geographic information in a micro-computer. He stressed further that the geographic data which is stored describes objects from the real world in terms of their position on the earth with respect to a known coordinate system, their attributes which are unrelated to their positions and their spatial interrelations with objects around them. GIS has the ability to quickly manipulate, analyze, display geographic data and also retrieve the existing data and compare if necessary in order to predict what is likely to happen in the future [53]. GIS is any system that captures, stores, analyze, manages, and present data that are linked to location. In Port Harcourt, extensive studies on flood like [55] [53] [56] had been carried out using conventional methods but the application of GIS in monitoring flooding seems to be deficient. GIS as a useful and important technique to monitor flood. The proper monitoring and forecasting of flood will help in the proper allocation of the urban land use and to a greater extent give warnings to the flood prone areas in the cities which help to reduce the havoc or lost caused by flood.

In this study, Ikwerre LGA and its environs was designated to demonstrate an in-depth study to detect communities and their environs that are most susceptible to recurrent flooding using Remote Sensing and GIS techniques. These techniques lessens an orderly bias in data assembly and large extents of land can be controlled and monitored at a look. The choice of this area for this study was due to the recurrent riverine flood events that damage infrastructure, buildings, farmland and causes displacement to people and home. The purpose of this study will be achieved through the following objectives: to track record of the prior flooding in the area; to obtain elevation data from remote sensing; identify geospatial locations of the communities using GPS; to survey the relationship between the two data using Geographical Information Systems. Findings in this research will identify Flood-prone areas in the Ikwerre Local Government area with the view to sensitize the public to be at alert and local authorities to take measures to mitigate the destructive effects of flood menace in the study area.

2. MATERIALS AND METHODS

2.1 The Study Area

Ikwerre local government area is one of the twenty three local government area in Rivers State, and one of the major ethnic group in the Niger Delta. Ikwerre local government is the mother of Ikwerre ethnic nationality. The local government area is rich with land and natural resources, such as land, soil, vegetation, water, coal, petroleum, gas, animals, wildlife, air, wind and atmosphere, clay, sand and gravel [57]. The population of the area therefore increases on a daily basis. It has an average of 2.8% growth rate per annum which puts the population of the Local Government Area as at 2006 to be 189,726 people [58]. The local government area has its headquarters at Isiokpo the ancient kingdom of Ikwerre Nation.

The study area is bounded by Obio/Akpor (local government area) to the south, Etche to the east, Emohua to the west and Imo State to the north (see Fig. 1). Ikwerre Local government area lies between latitudes 4°58’ 33”N and longitudes 6°53' 21’’E. The local government area covers 530 km^2 (1,380sq mi) [59]. The study area communities is drained by rivers and creeks known as ”Otamini River, Ntawogba creek and New Calabar River” with other distributaries of rivers network. Ikwerre local government area enjoy tropical hot monsoon climate as a result of her latitudinal position. The daily tropical monsoon climate is characterized by heavy rainfall and high temperature all year round [57]. The Communities experiences lengthy and heavy rainfall season and very short dry season. Rainfall in the study area is heavy and more persistent as a result of the strong influence of the southwest trade wind. Her rainfall is almost predictable and follows sequence of increase towards the month of July-August before decreasing in the month of November - February [57]. Rainfall is at its peak in July and September with a little dry season occurring in August, although the period of the break has been fluctuating in recent times. The study area experience a double maximum rainfall occurs between July and August. Although there might be rain during the months of December, January and February, most of the rains received are unreliable a spotty [60] [57] There is no year the length of rainy season is about 272 days. Rainfall in Ikwerre occurs over a long duration of usually between 2-4 hours and it is high intensity [60] [57].Temperature on the other hand is high and fairly constant throughout the year in Ikwerre. February is the warmest of all the months of the year with an average temperature of 32°C at noon, the month of July is the oldest. Like Port Harcourt metropolis, mean annual temperature in the study is based 28^0C while the mean daily maximum temperature is about 30^0C. The months of February, March and April records the highest mean maximum temperature. The maximum temperature also exhibits the same sequence [60] [57]. In addition to these, the study area experiences a seasonal variation in relative humidity. This is mainly due to the seasonal variation in the amount of isolation receives. Relative humidity is high in Ikwerre with mean annual figure of about 80%. The rainy season month records the highest value. These months are very cloudy due to the strong presence of the south westerly wind [61, 57].

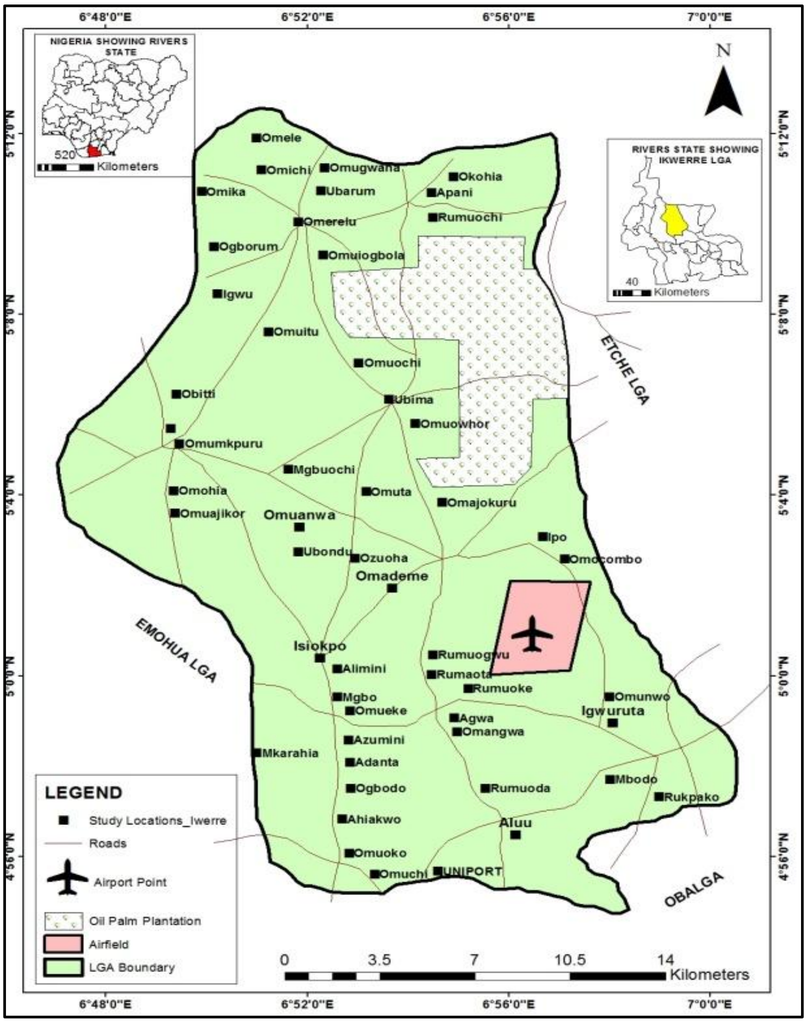

Fig. 1. Ikwerre L.G.A showing the communities
Source: River State Ministry of Lands and Survey, 2019

2.2 Methodology

2.2.1 Data collection and analysis

The Digital Elevation Model (DEM) data used in this research was an observation by environmental monitoring satellite called The Shuttle Radar Topography Mission (SRTM). The data have been enhanced to fill areas of missing data to provide more complete digital elevation data with a resolution of 3 arc-seconds for global coverage. The entity ID is SRTM3N12E004V2I downloaded via GloVis (https://glovis.usgs.gov/app). The area of interest was windowed using IDRISI Taiga to focus on the study area. The Google Earth Pro was used to identify and create point data for sampled communities within the study area (Table 1.). The created point data and the downloaded Digital Elevation Model (DEM) were merged together to create a single image (map overlay) using QGIS. This technique helps to visualize the interaction between the communities and the elevation. Similarly, the DEM was reformatted to contour lines that were overlaid by community locations data.

3. RESULTS AND DISCUSSION

The DEM on Fig. 2 shows that the sampled settlements were located between 20 and 30 meters elevation, but the entire study area ranges between 10 and 40 meters (ASL). This shows that the variation between the lowest and the highest locations in the study area is narrow (30 meters). The entire region has no definite river channel that take away surface water from the area. This makes most of the region liable to flash-flood. The contours on Fig. 3 confirmed that the sampled settlement were located between 20 and 30 meters (ASL).

The Plate 1 depicts how rain water stagnates within the community, even after an hour of rainfall. The areas are lowlands without enough drainage. The Plate 1 (a), (b) and (c) are Omuoda, Omuahunwo and Okparagwa respectively.

Fig. 4 is a result of image classification where DEM was used to grade surface area to identify flood-prone areas. The elevation 0-20, 20-30 and 30-46 were considered high, low and safe area respectively. The re-classed image was overlaid by community point data and the result shows that four communities were found to be at the high risk zone. The communities include Okparagwa, Omuahunwo, Omuoda and Uniport. While six communities were located within the low risk region, that include Omuolo, Imogu, Igwuruta, Mbodo, Omuchi and Agbada 2. The remaining two communities were at the safer grounds that include Omunwei and Omuohia.

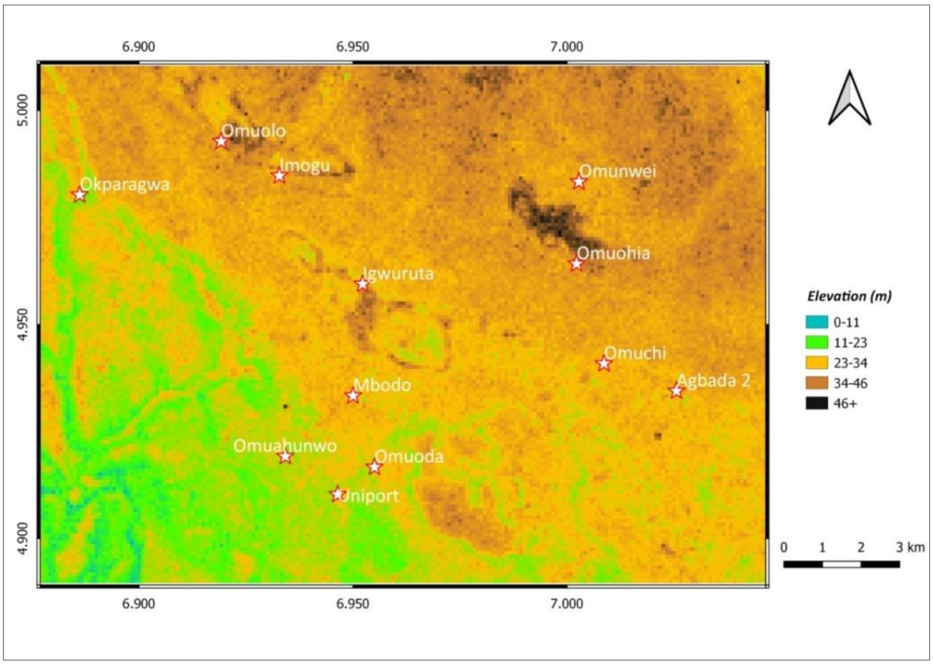

Fig. 2. Sampled communities on DEM

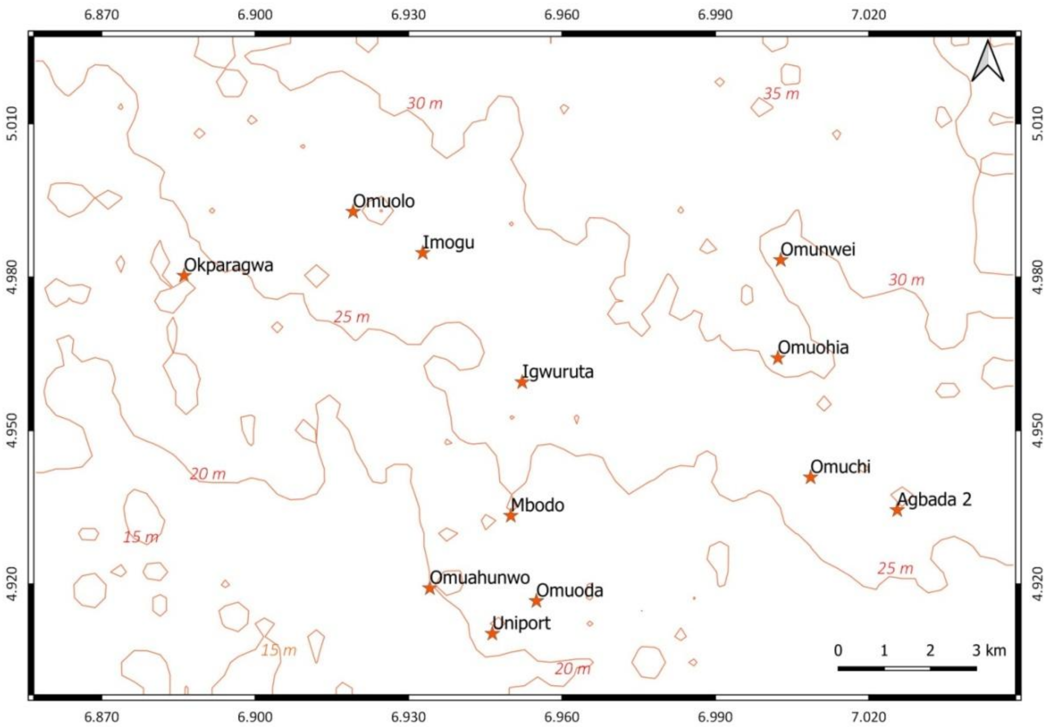

Fig. 3. Sampled communities on contours

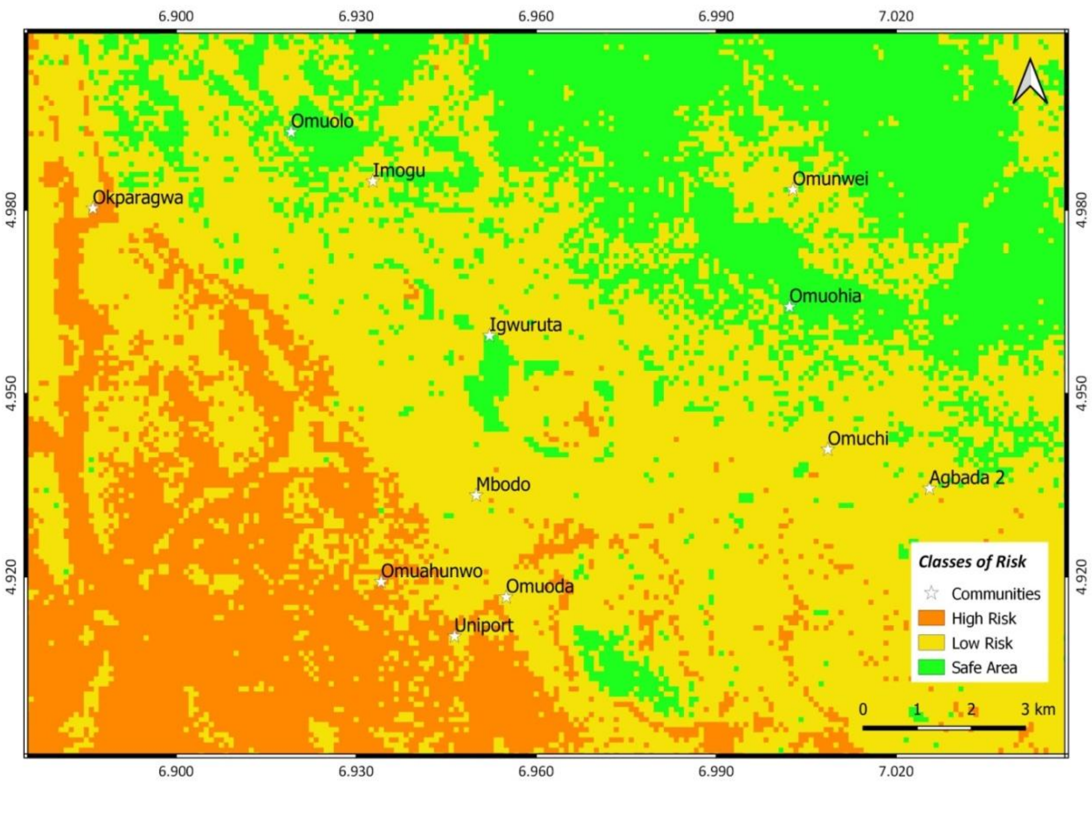

Fig. 4. Elevation classification

Table 1. Geographical locations of the sampled communities

S/N	Sampled Communities	Latitude	Longitude	Elevation in Meters	GPS Accuracy
01	Mbodo	04^0 55' 60"	006^0 57' 00"	25m	3m
02	Igwuruta	04^0 57' 34"	006^0 57' 08"	26m	3m
03	Omuoda	04^0 56' 00"	006^0 57' 18"	23m	3m
04	Omuahunwo	04^0 55' 09"	006^0 56' 03"	20m	3m
05	Okparagwa	04^0 58' 49"	006^0 53' 10"	24m	3m
06	Imogu	04^0 59' 05"	006^0 55' 58"	27m	3m
07	Omuolo	04^0 59' 34"	006^0 55' 09"	28m	3m
08	Omuohia	04^0 57' 51"	007^0 00' 08"	30m	3m
09	Omuchi	04^0 56' 27"	007^0 00' 31"	27m	3m
10	Agbada 2	04^0 56' 04"	007^0 01' 32"	27m	3m
11	Uniport	04^0 54' 37"	006^0 56' 47"	21m	3m
12	Omunwei	04^0 58' 60"	007^0 00' 10"	29m	3m

Source: Author's Field work, 2020

Plate 1. 2020 flood on the selected communities

4. CONCLUSION AND RECOMMENDATIONS

The Geographical Information System (GIS) is a robust system that enabled researchers to analyze spatial data and present the result in a geographical manner. It also reduces bias to a less significant level. The result of the analysis shows that the entire study area has no definite river channel that leads to flash flood whenever heavy rains fall. It also shows that the area is somewhat flat, with 30 meters difference between highest and lowest elevations. The four, out of twelve settlements were located at the high risk zone. The settlements are Uniport, Omuoda, Omuahunwo and Okparagwa. This confirmed the statement of Agbonkhese *et al.,* [50] that locations with inadequate drainages are liable to flood, especially in a relatively flat environment such as Ikwerre. It was recommended that the high risk zone in the area should be provided with artificial water channel that will contain and convey surface run-off to a nearby stream. The local authority should relocate the affected settlements to a safer zone.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Yalcin G, Akyurek Z. Analyzing flood vulnerable areas with multi-criteria evaluation. 2004; 6.
2. Forkuo EK. Flood Hazard Mapping using Aster Image data with GIS. International Journal of Geomatics and geosciences. 2011; 1(4):19.
3. Hapuarachchi HAP, Wang QJ, Pagano TC. A Review of advances in flash flood forecasting. Hydrological Processes. 2011; 25:2771–2784.
4. Wang Y, Li Z, Tang Z, Zeng G. A GIS-Based Spatial Multi-Criteria Approach for Flood Risk Assessment in the Dongting Lake Region, Hunan, Central China. Water Resources Management. 2011;25:3465–3484.
   DOI:10.1007/ s11269-011-9866-2.
5. Kebede B. Application of GIS and Remote Sensing Techniques for Flood Hazard and Risk Assessment: The Case of Dugeda Bora Woreda of Oromiya Regional State, Ethiopia. Paper for the 2012 Berlin Conference on the Human Dimensions of Global Environmental Change. 2012;17.
6. Duan W, He B, Takara K, Luo P, Nover D, Yamashiki Y, Huang W. Anomalous atmospheric events leading to Kyushu's flash floods, July 11–14, 2012. Natural Hazards. 2014;73(3):1255–1267.
7. Tsakiris G. Flood risk assessment: concepts, modelling, applications. Natural Hazards Earth System Sciences. 2014;14:1361–1369.
   DOI:10.5194/nhess-14-1361-2014.
8. Jeyaseelan AT. Droughts and floods assessment and monitoring using remote sensing and GIS. Satellite remote sensing and GIS applications in agricultural meteorology. 2003;291.
9. Danumah JH, Odai SN, Saley BM, Szarzynski J, Thiel M, Kwaku A, Kouame FK, Akpa LY. Flood risk assessment and mapping in Abidjan district using multi-criteria analysis (AHP) model and geo-information techniques, (cote d'ivoire). Geo-environmental Disasters. 2016;3:10
   DOI: 101186/s40677-016-0044-y. Springer Open Access.
10. Wizor CH, Mpigi GL. Geospatial Mapping of Urban Flood-Prone Areas in Port Harcourt Metropolis: Implications for Effective Urban Physical Planning in Nigeria. World Journal of Innovative Research (WJIR) ISSN: 2454-8236. 2020;8(1):17-25.
11. FEMA, Federal Emergency Management Agency. Floods and Floodplain Management; 2020.
    Available: www.fema.gov › nfip_sg_unit_1.
12. De Risi R, Jalayer F, De Paola F, Lindley S. Delineation of flooding risk hotspots based on digital elevation model, calculated and historical flooding extents: the case of Ouagadougou. Stochastic Environmental Research and Risk Assessment. 2018;32:1545–1559.
    Available: https://doi.org/10.1007/s00477-017-1450-8 Accessed 13 July 2020.
13. Kundzewicz ZW, Kanae S, Seneviratne SI, Handmer J, Nicholls N, et al. Flood risk and climate change: global and regional perspectives, Hydrolog. Sci. J. 2014;59:1-28.
14. Gill S. Literature Review: Impacts of Climate Change on Urban Environments – draft 30 Copy, with contributions from: Pauleit S, Ennos R, Lindley S, Handley J, Gwilliam J, Ueberjahn-Tritta, A., The Impact of Flooding on Urban and Rural Communities, Centre for Urban and Regional Ecology, University of Manchester, UK,; 2004.
15. CII (Climate Change and Insurance). Chartered Institute for Insurance, Research report of the Chartered Institute for Insurance, London; 2001.
16. Action Aid: Climate Change. Urban Flooding and the Rights of the Urban Poor in Africa: Key Findings from Six African Cities, Action Aid International, London; 2006.
17. McMichael AJ, Woodru RE, Hales S. Climate change and human health: Present and future risks, Lancet. 2006; 367:859–869.
18. Raaijmakers R, Krywkow J, Van der Veen A. Flood risk perceptions and spatial multi criteria analysis: an exploratory research for hazard mitigation, Nat. Hazards. 2008;46:307–322.
19. Umeuduji JE. Drainage Basin Dynamics, Emhai books Uniport; 2010.
20. Ayoade JO, Akintola FO. Public perception of flood hazard in two Nigerian cities, Environ. Int. 1980;4:277–280.
21. Adeloye AJ, Rustum, R. Lagos (Nigeria) flooding and influence of urban planning, Urban Design and Planning. 2011;164: 175–187.

22. Adelekan I. Private Sector Investment Decision in Building andConstruction: Increasing, Managing and Transferring Risks: Case Study of Lagos, Nigeria, The United Nations Office for Disaster Risk Reduction, Global Assessment Report on Disaster Risk Reduction. 2012;1–9.
23. Aderogba K. Qualitative studies of recent flood and sustainable growth and development of cities and towns in Nigeria, International Journal of Academic Research in Economics and Management Science. 2012a;1–25.
24. Oshodi L. Flood management and governance structure in Lagos, Nigeria, Regions Magazine. 2013;292:22–24.
25. Ajibade I, McBean G, Bezner-Kerr R. Urban flooding in Lagos, Nigeria: patterns of vulnerability and resilience among women, Global Environ. Change. 2013;23 :1714–1725.
26. Soneye A. An overview of humanitarian relief supply chains for victims of perennial flood disasters in Lagos, Nigeria (2010–2012), Journal of Humanitarian Logistics and Supply Chain Management. 2014;4: 179–197.
27. Houston D, Werritty A, Bassett D, Geddes A, Hoolachan A, McMillan M. Pluvial (Rain-Related) Flooding in Urban Areas: the Invincible Hazard, Joseph Rowntree Foundation, York, UK; 2011.
28. Odjugo PAO. An analysis of rainfall pattern in Nigeria, Global Journal of Environmental Sciences. 2006;4139–145.
29. Aderogba K. Global warming and challenges of floods in Lagos metropolis, Nigeria, Academic Research International. 2012b;2:448–468.
30. Odunuga S, Oyebande L, Omojola AS. Social-economic indicators and public perception on urban flooding in Lagos, Hydrology for Disaster Management: Special Publication of the Nigerian Association of Hydrological Sciences, NAHS, Abuja. 2012;82–96.
31. Lamond J, Bhattacharya N, Bloch R. The role of solid waste management as a response to urban flood risk in developing countries, a case study analysis, in: Flood Recovery Innovation and Response, edited by: Proverbs, D., Mambretti, S., Brebbia,C., and de Wrachien, D., WIT Press, Southampton. 2012;193–205.
32. Ojinnaka O. Hydrography in Nigeria and Research Challenges, FIG Working Week 2013, Environment for Sustainability, TS05E – Hydrographic Education and standards. 2013;6439:1-11., Abuja, Available:http://www.fig.net/pub/fig2013/papers/ts05e/TS05E_ojinnaka_6439.pdf (last access: 10 March 2015), 2013.
33. Abdullahi M, Yelwa SA. An Analysis of the Flood-Prone Areas in BirninKebbi, Using Remote Sensing and GIS. Journal of Geography, Environment and Earth Science International. 2020;(24)6:77-85. Article no.JGEESI.60865ISSN: 2454-7352.
34. Rigasa YA, Ekanem EJ, Badamasi AG. Flood risk reduction in Nigeria: a functional strategy for vulnerable communities. Biological and Environmental Sciences Journal for the Tropics. 2015; 12(1):670–674. ISSN 0794 – 9057.
35. FGN. Federal Government of Nigeria. Post-disaster needs assessment 2012 Flood. Accessed 02 September 2020. National Emergency Management Agency & World Bank; 2013. Available:https://www.gfdrr.org/sites/gfdrr/files/NIGERIA_PDNA_PRINT_05_29_2013 WEB.pdfAccessed 02 September 2020.
36. Richard D. Nigeria – Floods Affect Half a Million as Death Toll Rises. Flood list; 2018.
37. Ajibade I, Armah FA, Kuuire VZ, Luginaah I, McBean G, Tenkorang EY. Assessing the bio-psychosocial correlates of flood impacts in coastal areas of Lagos, Nigeria, J. Environ. Plann. Man. 2014;58:445–463. DOI:10.1080/09640568.2013.861811, 2014.
38. IFRC (International Federation of Red Cross and Red Crescent). Nigeria: Floods; 2011. Available at: http://reliefweb.int/disaster/ fl-2012-000138-nga (last access: 10 March 2015), 2012.
39. Oladunjoye M. Nigeria: July 10 Flooding – Lagos Gives Relief Materials to Victims,Daily Champion Newspaper; 2012.
40. Agbola T, Agunbiade E. Urbanization, slum development and security of tenure: The challenges of meeting millennium development goal (MDG 7) in metropolitan Lagos, Nigeria, in: PRIPODE Workshop, Nairobi, Kenya; 2007.
41. Nkwunonwo UC. Land use/land cover mapping of the Lagos metropolis of Nigeria using 2012 SLC-off Landsat ETMC Satellite Images, International Journal of Scientific and Engineering Research. 2013;4:1217–1223.

42. Oloke OC, Ijasan KC, Ogunde AO, Amusan LM, Tunji-Olayeni PF. Improving urban residents' awareness of the impact of household activities on climate change in Lagos State, Nigeria, Journal of Sustainable Development. 2013;6:56–64.
43. BNRCC. (Building Nigeria's Response to Climate Change): Vulnerability, Impacts and Adaptation, Climate Change in Nigeria; 2008.
Available:www.infoo@climatechange.org(last access: 10March 2015), 2008.
44. Ugwu LI, Ugwu DI. Gender, floods and mental health: the wayforward, International Journal of Asian Social Science. 2013;3:1030–1042.
45. Ajibola MO, Izunwanne EM, Ogungbemi AO. Assessing the effects of flooding on residential property values In Lekki Phase I, Lagos, Nigeria, International Journal of Asian Social Science. 2012;2:271–282.
Available:http://floodlist.com/africa/nigeriafloods-september-2018-update
Accessed 02 September 2020.
46. Olajuyigbe AE, Rotowa OO, Durojaye E. An assessment of flood hazard inNigeria: the case of mile 12, Lagos, Mediterranean Journal of Social Sciences. 2012;3:367–375.
47. Adelekan I. Vulnerability of poor urban coastal communities to flooding in Lagos, Nigeria, Environ. Urban. 2010;22:433–450.
48. Bashir O, Oludare H, Johnson O, Aloysius B. Floods of fury in Nigerian cities, Journal of Sustainable Development. 2012;5:69–79.
49. Huq S, Alam M. Flood management and vulnerability of Dhaka City. Building Safer Cities: The Future of Disaster Risk, Washington, D.C. 2003;121–135.
50. Agbonkhese O, Agbonkhese EG, Aka EO, Joe-Abaya J, Ocholi M, Adekunle A. Flood menace in Nigeria impacts, remedial and management strategies. Civil and Environemntal Research. 2014;6(4):32-40.
51. Finlayson CM, Gitay H, Bellio MG, Van Dam RA, Taylor I. Climate variability and change and other pressures on wetlands and water birds – impacts and adaptation. In: Boere G, Gailbraith C, Stroud D, editors. Water birds around the world. Edinburgh: Scottish Natural Heritage. 2006;88–9.
52. Finlayson CM. Climate change and wetlands .Springer Science + Business media. Dordrecht .The wetlands books; 2016.
DOI: 1011007/978-94-007-6172-8_126-1.
53. Ologunorisa ET. An Assessment of Flood Vulnerability Zones in the Niger Delta,Nigeria. International Journal of Environmental Studies. 2004;61(1):31-38.
54. Burroughs PA. Principles of Geographic Information Systems for Land Resource Assessment. Oxford: Clarendon Press. 1987;193.
55. Ologunorisa ET. An Assessment of Flood Risk in the Niger Delta, Nigeria. Unpublished Ph.D. Thesis, University of Port-Harcourt, Nigeria. 2001;303.
56. Ologunorisa TE. Strategies for Mitigation of Flood Risk in the Niger Delta, Nigeria. J. Appl. Sci. Environ. Manage. 2009;13(2):17- 22.
57. Wizor CH, Wali E. Peri-Urban Housing and Environmental Quality Problems in Choba Town, Rivers State, Nigeria. IIARD International Journal of Geography and Environmental Management E-ISSN 2505-8821 P-ISSN 2695-1886. 2019;5:2.
Available:www.iiardpub.org.
58. NPC, National Population Commission. Population distribution by sex, state, LGA's, senatorial district, 2006 Priority Tables. 2006;3.
59. Google Earth. Aerial view of Ikwerre Local Government Area; 2020.
60. Osuiwu BO, Ologunorisa TE. Weather and climate, in C.U Oyegun and A. Adeyemo (eds.), Port Harcourt Region. Paragraphics, 1999.
61. Flood list Africa. Niger – Flooding Reported in All Regions, Over 60 Dead and 100,000 Affected
Available:https://floodlist.com/africa/niger-flood-update-august-2021

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