International Journal Of Engineering Research And Development
e- ISSN: 2278-067X, p-ISSN: 2278-800X, www.ijerd.com
Volume 20, Issue 11 (November, 2024), PP 21-33

Mapping Flood Risk Zones in Asaba, Delta State, Nigeria Using Remote Sensing and GIS Approach

Ofido, W.I[1]., Ojiako, J.C[1] and Eze, C.G[2].
[1]*Department of Surveying and Geoinformatics, Nnamdi Azikiwe University Awka, Nigeria*
[2]*Department of Mathematics, Coal City University, Enugu*

Abstract- *flooding is a severe natural disaster affecting regions worldwide, including Nigeria. It can result from dam failures, rapid snowmelt, coastal events, and heavy rainfall, leading to life-threatening conditions, property damage, economic losses, and infrastructure disruption. Mapping flood risk zones in Asaba, Delta State is crucial due to frequent rainfall and its significant impacts. The aim of this study is mapping flood risk zones in Asaba, Delta State, Nigeria using Remote Sensing and GIS approach. The objectives are to; determine the levels of flood risk zones; assess the landcover/landuse affected areas by flood; develop a pairwise comparison matrix and Estimation of the Consistency Ratio; produce a flood vulnerability map showing levels of flood risk. The methodology adopted was Multi-Criteria Decision Making (MCDM) using Analytic Hierarchy Process (AHP) to assign weight (influence) on each criterion based on relative importance to each of the criteria layer maps created. The weighted layer maps are then overlaid, and development of a pairwise comparison matrix applied in order to perform Weighted Overlay Analysis. This is known as Weighted Linear Combination (WLC) Model. Nine (9) criteria were identified for flood risk zones. These criteria were assigned using Analytic Hierarchy Process (AHP) and the weights of the criteria layers were analyse using ArcGIS software version 10.7. A consistency ratio of 0.028 and consistency index of 0.026 was obtained. The result of weighted overlay analysis produced the final flood risk map with four hazard zones. Out of the total study area, very high-risk zone occupied 25.13% (5570.45ha); high risk zone occupied 27.17% (6022.23ha); moderate risk zone occupied 24.24% (5372.49ha) while low risk zone occupied 23.46% (5197.81ha). Four (4) levels of flood risk zones were identified in the study area.*
Keywords: *Asaba, Delta State, Flooding, GIS, Remote Sensing*

Date of Submission: 20-10-2024 Date of Acceptance: 04-11-2024

I. Introduction

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, (Kundzewicz et al, 2014).

Flood is a natural occurrence. It can be caused by varying factors such as heavy down pour of rain, river overflow, reservoir failure, dam breaking and strong wind in coastal areas. Other factors that can cause flood to take place include volcano, melting of ice and snow or glaciers, tidal surge data, tsunami due to undersea earthquakes, break of levees etc. Man made changes as a result of construction works can also cause flood to take place. Also, when there is low infiltration capacity and poor drainage, rise in hydrological water table above the surface results to flooding, sometimes this happens due to collapse of dams and when there is heavy rainfall, Nwilo (2013). Moreover, urbanization results into conversion of agricultural land, natural vegetation and wetlands to built-up environments and construction on natural drainages as well increase in the population of those living in flood vulnerable areas such as flood plains and river beds, (Adeoye et al, 2009). A common environmental problem in Nigeria is flood and it is said to occur when a body of water moves over and above an area of land which is not normally submerged. It could also be seen as the inundation of an area not normally covered with water, through a temporary rise in level of stream, river, lake or sea. (Nelson, 2001). Flooding is a serious environmental hazard which did not left Asaba and its environs out. It has caused several damaging effects on cultural and socio-economic wellbeing of the people in Asaba, the capital of Delta state.

The impacts of floods are more pronounced in low-lying areas. In more recent years, 2011 and 2012 appears to be the worst incidence of flooding in Nigeria with a lot of reported cases indicating how flood menace ravaged affected states of the country when water from the Lagdo Dam in Cameroon was released. Although the Nigerian Meteorological Agency (NIMET) had alerted Nigeria that there would be an above normal rainfall in strategic parts of the country which might lead to flooding incidents in 12 states of the federation, yet nobody gave consent to that warning. According to Suleiman et al (2014), the significance of the year 2012 flood disaster in Nigeria lies in the fact that they were unprecedented in the past forty years. 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. McGill (1998). 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 (ActionAid, 2006; McMichael et al., 2006; Raaijmakers et al., 2008).

The frequency of this phenomenon (flooding) is no longer news. Often flooding is a complex combination of various causes (coastal, fluvial and pluvial). In order to consider flood impacts in urban areas, general aspects of flood impacts should be addressed. Floods can impact human activities in many ways and this is why it is common to categorize these impacts. The flood consequences can be grouped as direct or indirect, tangible or intangible, or a combination of both. Direct damages occur if the asset of interest is physically exposed to flood waters (i.e., buildings, people or environment). Indirect damages are outside the flooded area and usually become apparent after a longer time. A classic example of indirect losses is the interruption of production in a firm that might occur due to a supplier affected by flooding. Traffic disruption due to floods is another indirect flood impact, the importance of which has not been studied in detail.

The small spatial and temporal scales of floods, relative to the sampling characteristics of conventional rain and discharge measurement networks, make also these events particularly difficult to observe and to predict (Borga, et al, 2014). Small streams in urban areas can also rise quickly after heavy rain due to higher generated run off and less concentration time (Ozcan and Musaoglu, 2010). Changes in the urban area and in storm intensity produce higher flows that exceed the capacity of small culverts under roads designed for non-urbanized areas. Although such structures can be adequate when designed, their capacity may turn out to be inadequate and thereby cause overflows onto the roads creating new water paths and flood the built-up areas. In developing countries, inadequate maintenance of the drainage channels, and debris and solid waste disposed into such drainage systems may accentuate the situation. The rainfall runoff process, however, is highly complex, non-linear and temporally and spatially varying because of the variability of the terrain and climate attributes, (Chang and Guo, 2006).

Recent efforts in hydrology have highlighted the need to consider the impact that society has on flooding (Baldassarre et al., 2013; Di Baldassarre et al., 2015). Of importance is determining the combination of physical processes and human dynamics that create conditions leading to flood disasters and increased human exposure to flooding. Physical processes can include long-term climatic changes that increase the occurrence of short-term extreme precipitation events triggering flash floods within rivers. Likewise changes in population, land use, and economics can encourage settlements within floodplains and subsequently create the need for flood protection measures (e.g. dams, levees, canals) that significantly alter river processes (Wohl et al., 2015). Globally these societal pressures are most apparent in urban areas that are undergoing rapid development (Seto et al., 2011) and an expected 60% increase in population (4 to 6 billion) by 2050 (United Nations, 2015). This projected urban expansion will mostly occur in Asia, specifically in locations with dense populations and low topography susceptible to flooding (Longman et al., 2012). For these reasons there is an urgent need to estimate flood exposure in Asaba as well as translate these estimates into actions to reduce exposure and disaster risk to urban inhabitants and critical infrastructure. The potential for flood casualties and damages is also increasing in many regions due to the social and economic development, which imply pressure on land-use, e.g., through urbanization. Flood vulnerability is expected to increase in frequency and severity, through the impacts of global change on climate, severe weather in the form of heavy rains and river discharge conditions (Dihn et al, 2014). It is understood that flood risks will not subside in the future, and with the onset of climate change, flood intensity and frequency will threaten many regions of the world (Jonkman and Dawson 2012).

One method to estimate flood exposure are computer models that generate predictions of flood inundation that can be spatially overlaid on maps of population, critical infrastructure, and income groups. For example, recent advances in reduced complexity flood models (Bates et al., 2010; Coulthard et al., 2013) with simplified physics have shown promise in estimating flood depths, extent and velocity in urban areas (Fewtrell et al., 2010; Ramirez et al., 2016; Sampson et al., 2015). These models are particularly suited for data sparse locations, with large spatial extents (>500 km2), and urban topography represented by fine spatial resolution (≤30 m) digital elevation models (DEMs). Moreover, open-source software and the low computational overhead needed for such reduced-complexity modelling facilitates the generation of multiple models runs that produce flood maps representing ensemble simulations of various flood scenarios. As such, flood exposure estimated with reduced-complexity models can explore uncertainty stemming from environmental forcings that result in various flood return periods and duration. Herein we use a freely available, reduced-complexity flood model to estimate flood exposure for the first time in a large, densely populated city in northwest India where human intervention (e.g. dam and levee construction) and demands on the hydrological cycle (e.g. water for irrigation) has contributed towards multiple catastrophic floods. Like many urban areas, flood mapping and exposure assessment in our study site is challenged by the scarcity of available data, in this paper methods to gather such data and forecast flood inundation using open-source software are presented. An important part of this research is how results from our model have directly motivated changes in the way local authorities are preventing future floods and increasing the resilience of the city.

Remotely sensed imagery and GIS can be very effective in identifying the spatial components of flood for management (Mohammad and Iyortim 2013). Remote sensing and GIS have played great role in mapping out areas prone to the vulnerability of flood. GIS is essential and such a powerful tool as an excellent software adopted in the analysis of flood vulnerability along flood plain zones. Its powerful features made it feasible to flood risk map by delineating the actual flood inclined zones. Such type of map can therefore help the responsible regulators to instantly appraise the likely effect of the flood tragedy and carry out a proper control mechanism to deal with predicted flood devastating impact. Mitigation of flood disaster can be successful only when detailed knowledge is obtained about the expected frequency, character, and magnitude of hazardous events in area as well as the vulnerability of people, buildings, infrastructures and economic activities in a potentially dangerous area (Van Western and Hosfstee 2000). Ishaya et al. (2009). A major strategy in mitigating the effects of flooding is by accurate mapping and delineating the vulnerability areas that will help determine the prevention measures to be adopted. To achieve this aim, reliable geospatial information is highly needed in order to evaluate the risk perception of the flooded area. A reliable approach and techniques of accessing geospatial information in the application of Remote Sensing and Geographic Inforrmation System (GIS).

GIS offers a wide range of application in pinpointing areas stricken by floods or foretelling areas which are more likely to be inundated by severe flooding (Lawal et al. 2014). In addition, GIS is certainly a program that could facilitate the planning bodies as well as floodplain administrators in identifying and delineating flood vulnerable zones within a given neighborhood. It aids geographical data storage into database, which can be queried and also presented graphically for analysis.

The state capital, Asaba experiences flood whenever it rained heavily. Other towns within the capital city such as Okpanam, Okwe, Oko, Anwai, Ugbolu, Ibusa, Achalla Ibusa, Issele-Azagba and Azagba-Ogwashi were also affected. DLA road, Ibusa road, Opkanam road, Jesus saves road, summit junction, Inter-Bua round-about, were not left out. Dennis Osadebe way and Nnebisi road which is the heart beat of the town and most busiest of all known as a commercial hub were also flooded, due to the topography and some blocked drainage system. It has become a devastating menace which destroyed properties, lives and other facilities beyond recognition and other roads within the state capital, destruction of social amenities, basic infrastructure and farmland within the river basins and forceful migration of people from flood risk zones.

Chaos in Asaba was noticed recently as flood sacked workers from offices. Many civil servants in Delta State were prevented from accessing their offices at the Old Secretariat Complex on Summit Road, due to flooding (Daily Post–Nigeria news, Nigerian newspaper 4th October, 2017). The flood was considered to be as a result of heavy rain downpour accompanied with thunder (lightening) in the area. The workers gathered at the entrance of the secretariat complex with their cars parked on the Summit Road as flood took over the area denying them access. It also caused havoc on the Okpanam Road under construction. Junior Staff Quarters Road, Direct Labour Agency (DLA) Road, Jesus Saves Road, West End Road, houses and areas around Shoprite were not spared as flood took over, while hindering vehicular and pedestrian movement.

Some motorists abandoned their cars after their vehicles plunged into flooded gullies and drains. Some schools at the Oko town were also submerged following the downpour. Social and psychological behaviour of the people were affected by flooding, and lives and properties were lost following the flooding of nearby towns, communities and their homes thereby causing the spreading and breeding of mosquitoes and tsetse flies as well as flooding of farm seeds and seedling during the farming season. It also caused over flow of agricultural farm land. At the Delta Broadcasting Service (DBS), off Okpanam Road, staffs who reported for morning duty were seen roaming about outside the main compound as the station remained off air, while office chairs, tables, computers, cameras, tapes, vital documents, records, as well as all writing materials and other personal belongings were seen floating on water.

At the secretariat housing, the offices of Establishment, Post Primary Education Board, (PPEB), Fire Service, part of the Ministry of Information, among others, civil servants were seen crowded at the main gate of the secretariat complex as vital official information regarding their work plunged into water. As mentioned earlier, flooding causes unnecessary biodiversity, destruction of farm produce thereby reducing the socio-economic activities and cash crops of the people who venture into agriculture. To effectively control the dynamics of flood disasters in the state capital, there is the need to find geospatial method of identifying and mapping potential flood risk zones, determining the extent of the land use and land cover changes and determining the effects of flood on affected victims. (Daily Post–Nigeria news, Nigerian newspaper 4th October, 2017). Abah (2013), Ejikeme et al (2015) and Onuigbo et al (2017) mapped flooding in various cities in Nigeria and have produced flood maps showing flood hazard zones. Hence, it is difficult to capture, quantify and understand flood hazard in full by visual observation only. This study intends to adopt remote sensing and GIS technology in identifying flood prone zones within the state capital and will serve as a valuable or essential tool in proper management of this devastating environmental hazard which seasonally affects the state capital annually.

1. Materials and Methods

1.1. Study Area

The Town of Asaba, the capital of oil rich Delta State (the Big Heart) of Nigeria is strategically located on a hill at the western edge of the majestic River Niger. (See fig.3.1a and 3.1b). The historic River Niger is a trans-African link beginning from other West African countries and down into the Atlantic Ocean. Asaba forms a connector between western, eastern and northern Nigeria through the River Niger from the north and via the Onitsha Niger Bridge, an East West link and a Nigeria Landmark. Asaba lies at Lat. 6° 08' 00” to 6° 16' 00”N, and Long.6° 38' 00” to 6° 45' 00”E, about 160km (100miles) North of where the River Niger flows into the Atlantic Ocean. (See fig.3.1c). The greater Asaba occupy an area of about 300sq.km (Asaba Meteorological Bulletin, 2007). It maintains an average tropical temperature of 32 °C during the dry season and an average fertile rainfall of 2,700mm (106 in) during the rainy season (Asaba Meteorological Station, 2007). Igbo is the native language in Asaba and neighbouring towns (the people of Anioma). Since becoming the Delta State capital, Asaba has grown in population to over a million (National Population Commission, 2006 estimate). The people are very hospitable and maintain a cosmopolitan international population.

1.2. Methods

The research methodology implemented for flood risk zoning involved a robust Multi-Criteria Decision-Making (MCDM) framework, leveraging the Analytic Hierarchy Process (AHP) to systematically assign weights to each criterion. This approach was chosen for its ability to incorporate expert judgment and prioritize criteria based on relative importance. In this study, AHP was employed to quantify the influence of each criterion, structuring it within a hierarchical framework that facilitated the pairwise comparison of criteria layers. These layers included environmental and socio-economic factors essential for delineating flood-prone zones.

The nine criteria identified for flood risk assessment included topography, land use, soil type, rainfall intensity, proximity to rivers, population density, drainage density, slope, and elevation. Each criterion was represented as a layer in a Geographic Information System (GIS), and its significance was determined relative to the other factors through AHP. Pairwise comparisons between these criteria were conducted, allowing for the generation of a weighted overlay map, thus utilizing the Weighted Linear Combination (WLC) Model to aggregate and analyze the influence of each criterion across the study area. The weighted criterion layers were combined in ArcGIS software version 10.7, where the Weighted Overlay Analysis was executed. A key aspect of this process was validating the consistency of expert judgments in assigning weights. The Consistency Ratio (CR) of 0.028 and Consistency Index (CI) of 0.026 indicated a high level of reliability in the pairwise comparisons, suggesting minimal inconsistency in the weight allocation process. These metrics confirmed the robustness of the weight distribution, ensuring that the analysis aligned closely with actual flood risk patterns within the study area.

The integration of the weighted criteria using WLC facilitated the generation of a spatial flood risk map, pinpointing zones of varying vulnerability. This GIS-based approach provided a comprehensive view of flood risk levels and enabled further scenario analysis to predict the potential impact of changing environmental conditions. The resulting flood risk map is a valuable tool for urban planners, policymakers, and stakeholders, allowing them to make informed decisions about flood mitigation and emergency response planning.

II. Results

2.1 Flood Risk Zones

Despite the fact that Slope, Elevation, Distance from drainage network and flow accumulation are some of the important parameters in defining flood hazard, slope has more relative weight as compared to other criteria. The analysis reveals that Slope contributed more to flooding than other factors considered in the model.

The weighted linear combination ranking technique (WLCRT) is based on the linear combinations of matrix calculations. It is formulated from a decision matrix of preferences, and the criteria weights are elicited from the proximity matrix of preference relations, using the eigenvector method.

The results of the weighted linear combination (WLC) analysis (see table 4.10) produced a layer showing four hazard zones; namely very high risk, high risk, moderate risk and low risk flood zones in the study area.

The Calculate Geometry tool allows you to access the geometry features in a layer. The tool can calculate coordinate values, length, and areas, depending on the geometry of the input layer. The results indicated that very high-risk zone occupied 25.13% of the entire study area, covering an area of 5570.45 hectares, while high risk zone occupied 27.17 %, covered an area of 6022.23 hectares. Moderate risk zone occupied 24.24% covering 5372.49 hectares while low risk zone occupied 23.46% covering an area of 5197.81 hectares. This is distribution is also represented in table 1 and figure 2.

Table 1: Flood hazard zone distribution

S/N	Name	Area	Percentage
1	Very High Risk	5570.45	25.13
2	High Risk	6022.23	27.17
3	Moderate Risk	5372.49	24.24
4	Low Risk	5197.81	23.46
	Total	22162.98	100

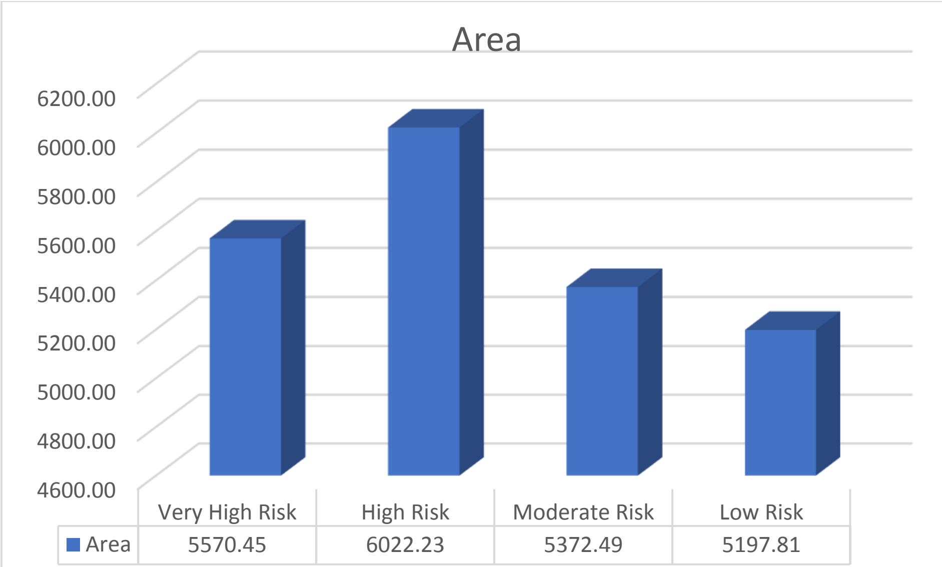

Fig 2: Bar Graph of flood hazard distribution

As illustrated on Figure 4.8 above, the bar graph (bar chart or column chart) shows information or a pictorial representation about the four (4) flood hazard zone distribution values for levels of very high risk, high risk, moderate risk and low risk flood zones in the study area as bars. Risk zones are plotted on one chart axis (x-axis) and values (Area) are plotted on the other axis (y-axis). Each risk zone claims one bar and the length of each bar corresponds to the bar's value. The larger the bar, the higher the value for the individual category. Overall, high risk has the largest bar with an area of 6022.23 hectares mostly part of the state capital Asaba, Anwai and Okwe town followed by very high risk with an area of 5570.45 hectares mostly in Oko town along riverine areas, then moderate risk with an area of 5372.49 hectares mostly part of Asaba and Ibusa town, while low risk has the smallest bar with an area of 5197.81 hectares mostly in Okpanam and Ibusa town.

3.2. Feature class at risk of Flooding

3.2.1 Features at very high-risk flooding

An overlay analysis was done, overlaying the flood risk layer with the landcover/landuse layer to determine areas at risk. The results in shown in figure 4.2.

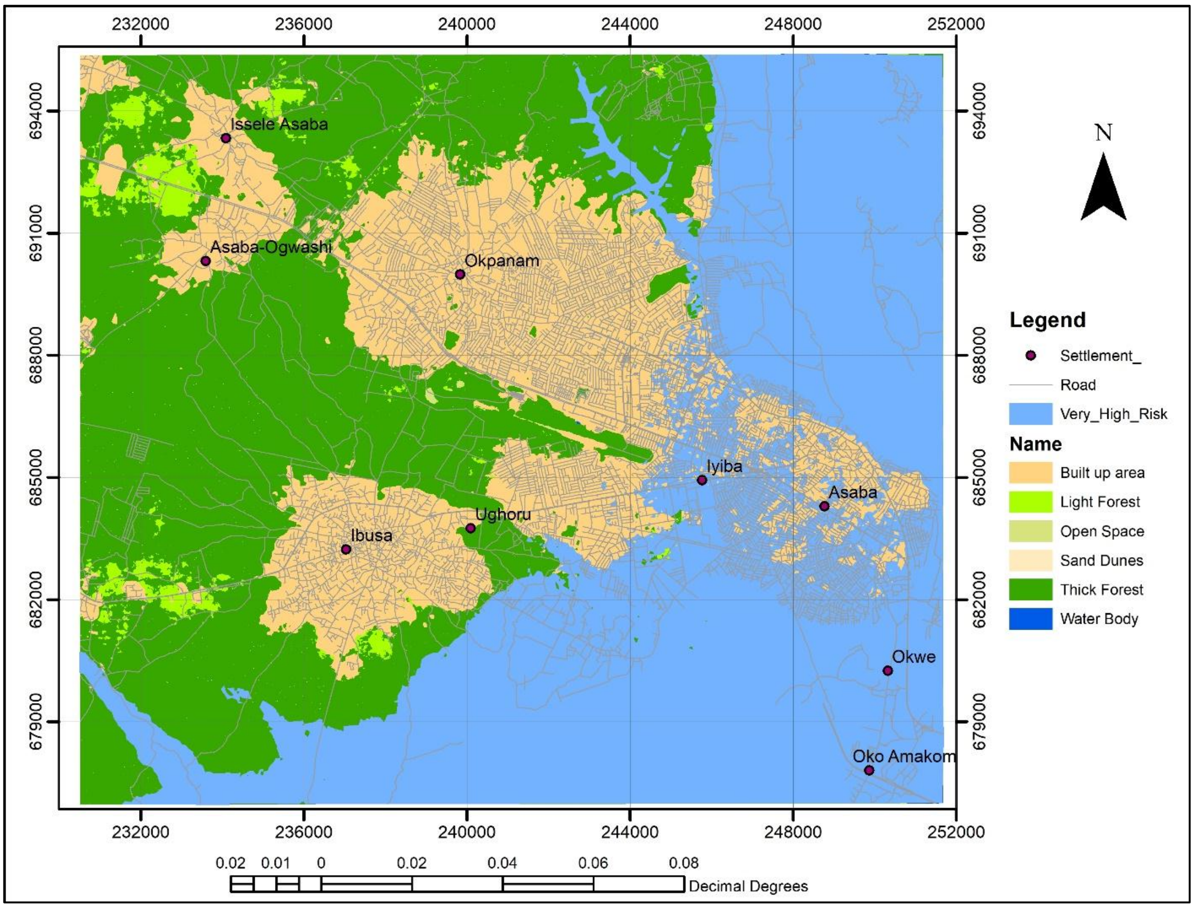

Fig 2: Feature class at risk of very high-risk flooding

The results in figure 2 showed that built up area had 22.49% with an area of 1250.90 hectares in very high-risk area. Communities under built up areas include: cable point, umuonaje, isieke all in the town of Asaba. Oko Amakam, Oko Anara, Obi okpu, and Oko camp communities all in the town of Oko. Light forest had 15.15% and an area of 842.85 hectares, communities include Isieke, and Cable point, in the town of Asaba, Oko Amakam, Oko Anara, Obi okpu, and Oko camp, in Oko town. Open space had 17.23% with an area of 3819.14hectares, communities include Akwuofor, and Ikpoto, in the town of Asaba. Sand dunes had 0.72% with an area of 160.63 hectares communities include Cable point, Akwuofor, and Ikpoto, in the town of Asaba.

Thick forest had 22.91% with an area of 5076.27 hectares, communities include Oko Amakam, Oko Anara, Obi okpu, and Oko camp, and waterbody had 5.02% with an area of 1112.23 hectares. Communities include cable point, Oko Amakam, Oko Anara, Obi okpu, and Oko camp.

The distribution of class within the very high-risk flood zone is shown in table 2 and fig 3.

Table 2: Distribution of feature class at risk of very high-risk flooding

S/N	Class Name	Area	Percentage
1	Built up area	1250.90	22.49
2	Light Forest	842.85	15.15
3	Open space	909.26	16.35
4	Sand Dunes	144.56	2.60
5	Thick Forest	1303.43	23.43
6	Waterbody	1111.01	19.97
	Total	5562.01	100

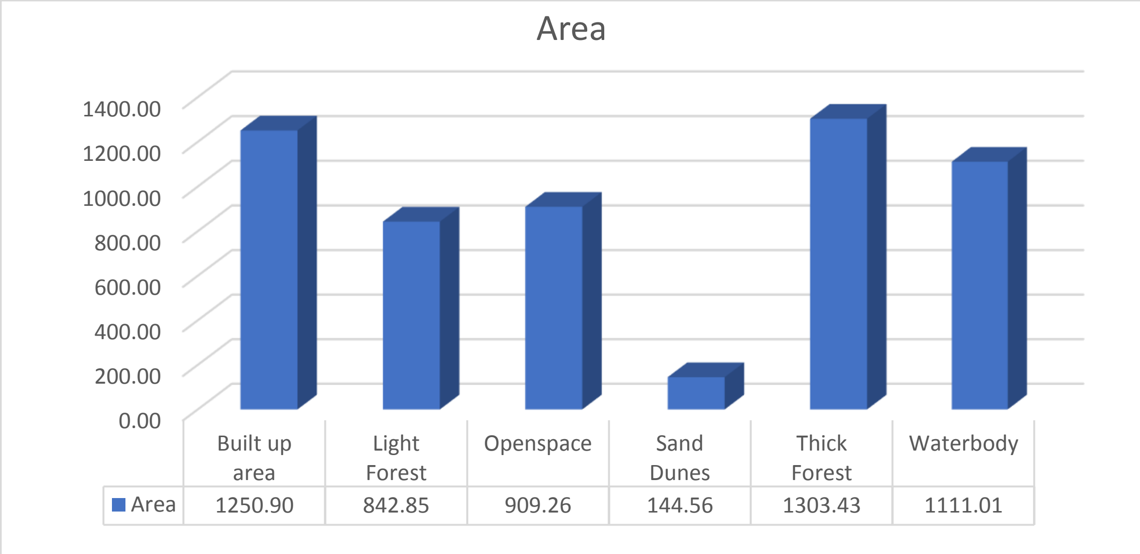

Fig 3: Features at very high risk

As illustrated on Figure 4.10 above, the bar graph (bar chart or column chart) shows information or a pictorial representation about the LCLU values for levels of a categorical feature as bars. Class features are plotted on one chart axis (x-axis) and values (Area) are plotted on the other axis (y-axis). Each class feature claims one bar and the length of each bar corresponds to the bar's value. The larger the bar, the higher the value for the individual category. Overall, Thick Forest has the largest bar with an area of 1303.43 hectares mostly in communities such as Oko Amakam, Oko Anara, Obi Okpu, Oko camp, while sand dunes have the smallest bar with an area of 144.56 hectares mostly in communities like Cable point in Asaba, along riverine areas.

3.2.2. Features at high-risk flooding

The overlay results showing feature class at risk of high-risk flooding is shown in fig 4

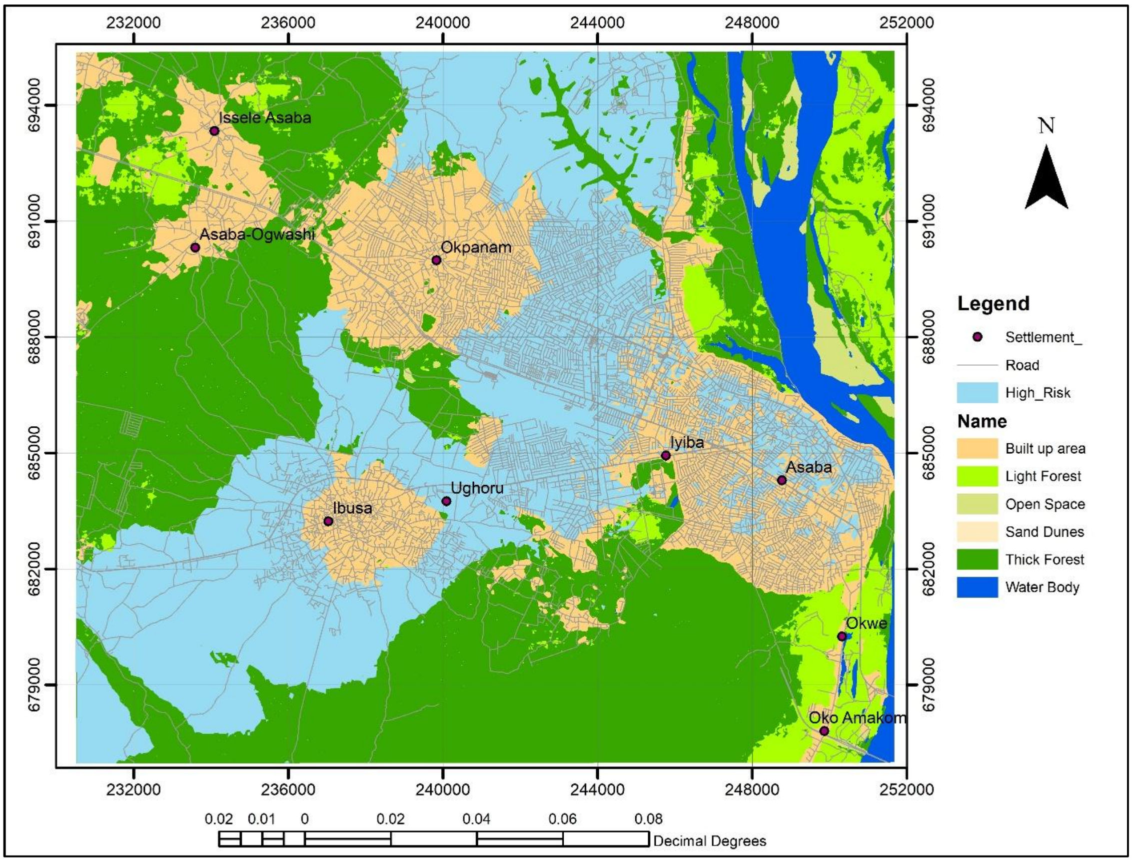

Fig 4: Feature class at risk of high-risk flooding

The results in figure 4 showed that built up area had 41.73% with an area of 2511.39 hectares in high-risk area, with communities affected which include Umuonaje, Isieke, Umuagu, Ezenei, Umuaji, Ugbomanta, in the town of Asaba, and Okwe town. Light forest had 13.16% and an area of 792.19 hectares. Affected communities include Ugbomanta, Ezenei in Asaba town, and Okwe town. Open space had 10.66% with an area of 641.67 hectares. Affected communities include Umuaji, Isieke in Asaba town, and Okwe town Sand dunes had 0.09% with an area of 5.13 hectares. Affected communities include Isieke in Asaba town, other town include Okwe. Thick forest had 34.35% with an area of 2067.32 hectares. Affected communities include Isieke and Okwe town and waterbody had 0.01% with an area of 0.57 hectares. Affected communities include Cable point in Asaba, and Okwe town. The distribution of class within the high-risk flood zone is shown in table 3 and fig 5.

Table 3: Distribution of feature class at risk of high-risk flooding

S/N	Class Name	Area	Percentage
1	Built up area	2511.39	41.73
2	Light Forest	792.19	13.16
3	Open space	641.67	10.66
4	Sand Dunes	5.13	0.09
5	Thick Forest	2067.32	34.35
6	Waterbody	0.57	0.01
	Total	6018.26	100.00

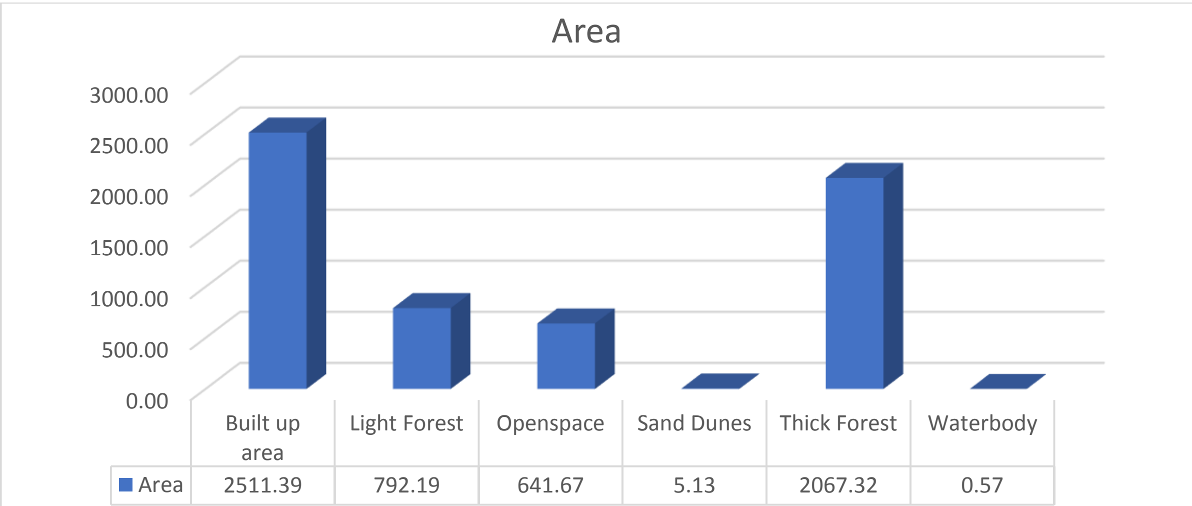

Fig 5 Feature class at risk of high-risk flooding

As illustrated on Figure 4.12 above, the bar graph shows information or a pictorial representation about the LCLU values for levels of a categorical feature as bars. Class features are plotted on one chart axis (x-axis) and values (Area) are plotted on the other axis (y-axis). Each class feature claims one bar and the length of each bar corresponds to the bar's value. The larger the bar, the higher the value for the individual category. Overall, Built up area has the largest bar with an area of 2511.39 hectares mostly in communities such as Umuonaje, Isieke, Umuagu, Ezenei, Umuaji, Ugbomanta, in Asaba town, and Okwe in Okwe town, while sand dunes and water body have the smallest bar with an area of 5.13 hectares and 0.57 hectares respectively, mostly in communities like Cable point in Asaba, along riverine areas.

3.2.3 Features at risk of Moderate risk flooding

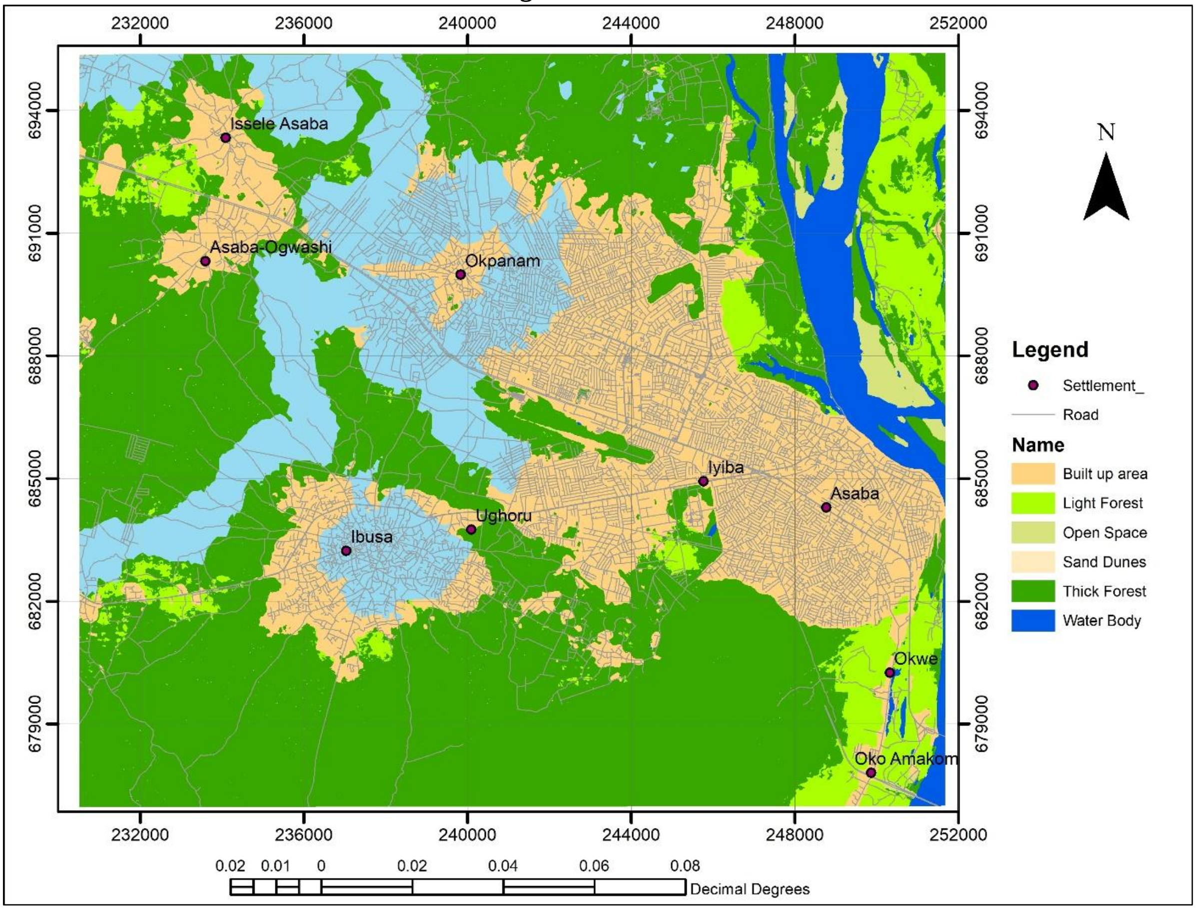

Fig 6 Feature class at risk of moderate-risk flooding

The results in figure 6 showed that that built up area had 39.09 % with an area of 2099.05 hectares in moderate risk area. Affected communities include Umuagu, Ezenei in Asaba, Okotomi in Okpanam town. Light forest had 22.05% and an area of 1184.14 hectares. Affected areas include Ogbeozoma community in Okpanam town, Umuodafe community in Ibusa town. Open space had 19.37% with an area of 1040.42 hectares. Affected areas include Obodogba community in Okpanam, Ezukwu community in Ibusa town. Sand dunes had 0.02% with an area of 1.32 hectares. Affected areas include Idigbe-ocha community in Okpanam town, Ogbeowelle community in Ibusa town. Thick forest had 19.46% with an area of 1044.75 hectares. Affected areas include Umuchima community in Okpanam town, Okponta community in Ibusa town. Waterbody had 0.0041% with an area of 0.22 hectares. Affected areas include Obodogwugwu community in Okpanam town, Umuezebo community in Ibusa town. The distribution of class within the moderate-risk flood zone is shown in table 4 and fig 6

Table 4: Distribution of feature class at risk of moderate-risk flooding

S/N	Class Name	Area	Percentage
1	Built up area	2099.05	39.09
2	Light Forest	1184.14	22.05
3	Open space	1040.42	19.37
4	Sand Dunes	1.32	0.02
5	Thick Forest	1044.75	19.46
6	Waterbody	0.22	0.0041
	TOTAL	5369.90	100

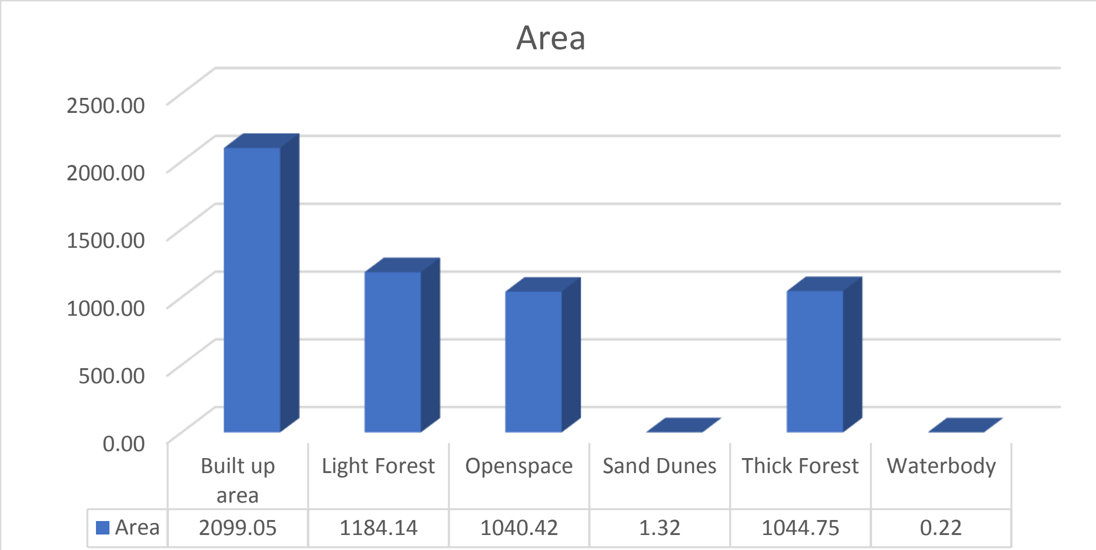

Fig 6: Feature class at risk of moderate-risk flooding

As illustrated on Figure 6 above, the bar graph shows information or a pictorial representation about the LCLU values for levels of a categorical feature as bars. Class features are plotted on one chart axis (x-axis) and values (Area) are plotted on the other axis (y-axis). Each class feature claims one bar and the length of each bar corresponds to the bar's value. The larger the bar, the higher the value for the individual category. Overall, Built up area has the largest bar with an area of 2099.05 hectares mostly in communities such as Okotomi, Umuchima, Umuodafe, in Okpanam town, while sand dunes and water body have the smallest bar with an area of 1.32 hectares and 0.22 hectares respectively, mostly in communities like Isieke, and Cable point in Asaba, along riverine areas.

3.2.4 Features at risk of Low-risk flooding

The overlay results showing feature class at low-risk flooding is shown in fig 7

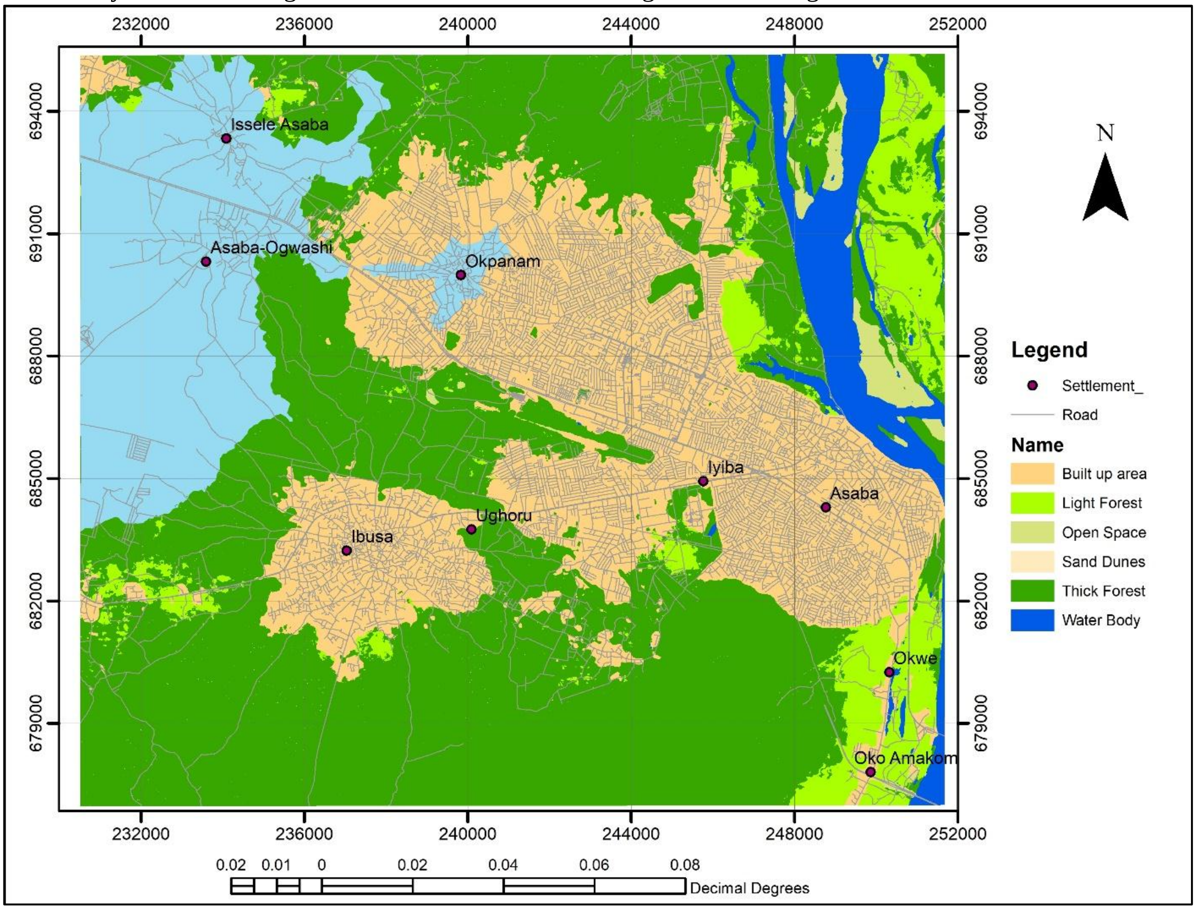

Fig 7: Feature class at low-risk flooding

The results in figure 7 showed that that built up area had 35.38 % with an area of 1837.05 hectares in low-risk area while light forest had 28.29% and an area of 1469.12 hectares, open space had 23.58% with an area of 1224.37 hectares, sand dunes had 0.18% with an area of 9.45 hectares, thick forest had 12.57% with an area of 652.54 hectares. Communities that fall under this low-risk flood zone include; Ogbeozoma, Obodogwugwu, Obodogba, Ogbeowelle, and Amachai in Okpanam town. Also, communities like Umuodafe, Okponta, Mkpayala, Umuneze, Umuehea, Umueze and Ezukwu in Ibusa town. The distribution of class within the low-risk flood zone is shown in table 5 and fig 8.

Table 5: Distribution of feature class at low-risk flooding

S/N	Class Name	Area	Percentage
1	Built up area	1837.05	35.38
2	Light Forest	1469.12	28.29
3	Open space	1224.37	23.58
4	Sand Dunes	9.45	0.18
5	Thick Forest	652.54	12.57
	Total	5192.53	100

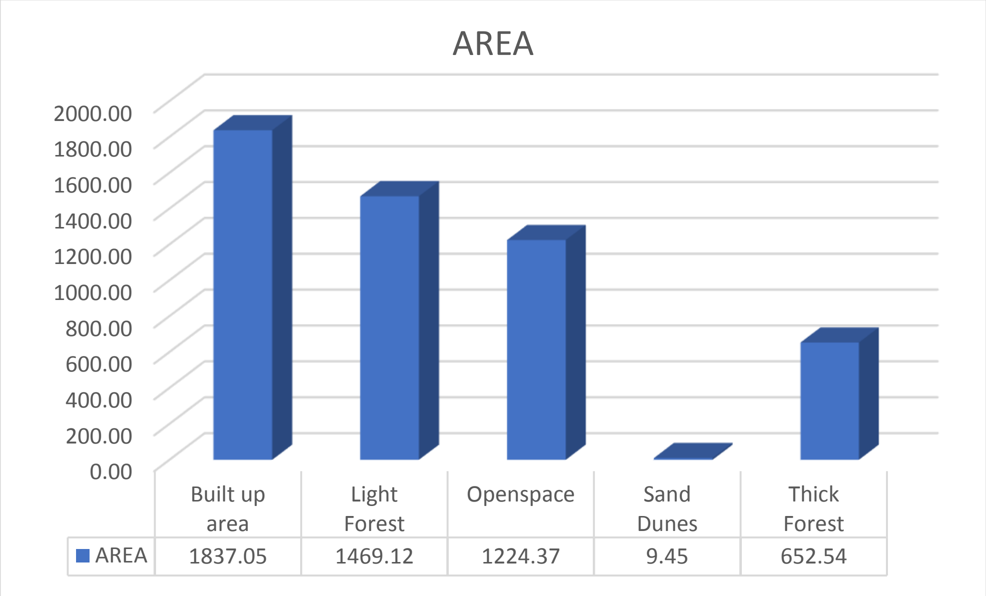

Fig 8 Feature class at risk of low-risk flooding

As illustrated on Figure 8 above, the bar graph shows information or a pictorial representation about the LCLU values for levels of a categorical feature as bars. Class features are plotted on one chart axis (x-axis) and values (Area) are plotted on the other axis (y-axis). Each class feature claims one bar and the length of each bar corresponds to the bar's value. The larger the bar, the higher the value for the individual category. Overall, built up area has the largest bar with an area of 1837.05 hectares. While sand dunes has the smallest bar with an area of 9.45 hectares. Both class features are found mostly in Okpanam and Ibusa town.

III. Conclusion

Flood hazard mapping is a vital component for appropriate land use planning in flood-prone areas. It creates easily-read, rapidly-accessible charts and maps which facilitate the identification of areas at risk of flooding and also helps prioritize mitigation and response efforts. Its aim was to map flood risk zones in Asaba, the capital territory of Delta state using Remote Sensing and Geographical Information System approach.

The results of the weighted linear combination analysis produced a layer showing four hazard zones; namely very high risk, high risk, moderate risk and low risk flood zones in the study area. Very high-risk zone occupied 25.13% of the entire study area, covering an area of 5570.45 hectares, while high risk zone occupied 27.17 %, covered an area of 6022.23 hectares. Moderate risk zone occupied 24.24% covering 5372.49 hectares while low risk zone occupied 23.46% covering an area of 5197.81 hectares. The results also showed that that built up area had 22.49% with an area of 1250.90 hectares, light forest had 15.15% and an area of 842.85 hectares, open space had 17.23% with an area of 3819.14hectares, sand dunes had 0.72% with an area of 160.63 hectares thick forest had had 22.91% with an area of 5076.27 hectares and waterbody had 5.02% with an area of 1112.23 hectares, all these are at very high-risk zone.

Also, the following classes were found to be in high-risk zone: built up area with 41.73% with an area of 2511.39 hectares, light forest had 13.16% and an area of 792.19 hectares, open space had 10.66% with an area of 641.67 hectares, sand dunes had 0.09% with an area of 5.13 hectares, thick forest had 34.35% with an area of 2067.32 hectares and waterbody had 0.01% with an area of 0.57 hectares. Also, in moderate risk zone, built up area had 39.09 % with an area of 2099.05 hectares, light forest had 22.05% and an area of 1184.14 hectares, open space had 19.37% with an area of 1040.42 hectares, sand dunes had 0.02% with an area of 1.32 hectares, thick forest had 19.46% with an area of 1044.75 hectares and waterbody had 0.0041% with an area of 0.22 hectares. Lastly, in low-risk zone, built up area had 35.38 % with an area of 2099 hectares, light forest had 28.29% and an area of 1469.12 hectares, open space had 23.58% with an area of 1224.37 hectares, sand dunes had 0.18% with an area of 9.45 hectares, thick forest had 12.57% with an area of 652.54hectares.

References

[1]. Adeoye, N. O., Ayanlade, A., & Babatimehin, O. (2009). Climate change and menace of floods in Nigerian cities: Socio-economic implications. Advances in Natural and Applied Sciences, 3(3), 369–377.

[2]. ActionAid. (2006). Climate change, urban flooding and the rights of the urban poor in Africa: Key findings from six African cities. ActionAid International.

[3]. Baldassarre, G. D., Montanari, A., Lins, H., Koutsoyiannis, D., Brandimarte, L., & Blöschl, G. (2013). Flood fatalities in Africa: From diagnosis to mitigation. Geophysical Research Letters, 40(18), 5149–5153. https://doi.org/10.1002/grl.51061

[4]. Bates, P. D., Horritt, M. S., & Fewtrell, T. J. (2010). A simple inertial formulation of the shallow water equations for efficient two-dimensional flood inundation modelling. Journal of Hydrology, 387(1–2), 33–45. https://doi.org/10.1016/j.jhydrol.2010.03.027

[5]. Borga, M., Anagnostou, E. N., Blöschl, G., & Creutin, J. D. (2014). Flash flood forecasting, warning and risk management: The HYDRATE project. Environmental Science & Policy, 18, 3–9. https://doi.org/10.1016/j.envsci.2011.12.007

[6]. Chang, T. J., & Guo, J. C. Y. (2006). Urban flood modeling. In J. C. Y. Guo (Ed.), Urban flood control and risk management (pp. 167–198). ASCE Publications.

[7]. Coulthard, T. J., Neal, J. C., Bates, P. D., Ramirez, J., de Almeida, G. A. M., & Hancock, G. R. (2013). Integrating the LISFLOOD-FP 2D hydrodynamic model with the CAESAR model: Implications for modelling landscape evolution. Earth Surface Processes and Landforms, 38(15), 1897–1906. https://doi.org/10.1002/esp.3478

[8]. Daily Post. (2017, October 4). Chaos as flood sacks Delta State workers from offices. Daily Post Nigeria. Retrieved from https://dailypost.ng

[9]. Di Baldassarre, G., Kooy, M., Kemerink, J. S., & Brandimarte, L. (2015). Floods and societies: The spatial distribution of water-related disaster risk and its relation to urbanisation, water demand, and the population density in the floodplains. Environmental Research Letters, 10(7), 074010. https://doi.org/10.1088/1748-9326/10/7/074010

[10]. Dihn, Q., Balica, S., Popescu, I., & Jonoski, A. (2014). Climate change impact on flood hazard, vulnerability and risk of the Long Xuyen Quadrangle in the Mekong Delta. Natural Hazards, 71(1), 469–491. https://doi.org/10.1007/s11069-013-0924-4

[11]. Fewtrell, T. J., Duncan, A., Sampson, C. C., Neal, J. C., & Bates, P. D. (2011). Benchmarking urban flood models of varying complexity and scale using high resolution terrestrial LiDAR data. Physics and Chemistry of the Earth, Parts A/B/C, 36(7–8), 281–291. https://doi.org/10.1016/j.pce.2010.12.011

[12]. Ishaya, S., Ifatimehin, O. O., & Okafor, C. (2009). Mapping flood vulnerable areas in a developing urban centre of Nigeria. Journal of Sustainable Development in Africa, 10(4), 153–172.

[13]. Jonkman, S. N., & Dawson, R. J. (2012). Issues and challenges in flood risk management–Editorial for the special issue on flood risk management. Water Management, 165(2), 65–70. https://doi.org/10.1680/wama.2012.165.2.65

[14]. Kundzewicz, Z. W., Kanae, S., Seneviratne, S. I., Handmer, J., Nicholls, N., Peduzzi, P., ... & Burkett, V. (2014). Flood risk and climate change: Global and regional perspectives. Hydrological Sciences Journal, 59(1), 1–28. https://doi.org/10.1080/02626667.2013.857411

[15]. Lawal, K. A., Agunbiade, M. E., & Omowaye, F. F. (2014). Assessment of flood risk zones for disaster management in Nigeria. Scientific Research Journal (Scirj), 2(4), 10–17.

[16]. Longman, R. J., Van Vliet, J., & Verburg, P. H. (2012). The global impact of urbanization on agricultural land: A meta-analysis of land use change between 1988 and 2008. Global Environmental Change, 22(3), 731–742. https://doi.org/10.1016/j.gloenvcha.2012.04.004

[17]. McGill, A. (1998). Flood hazard and floodplain management. UNESCO Press.

[18]. McMichael, A. J., Woodruff, R. E., & Hales, S. (2006). Climate change and human health: Present and future risks. The Lancet, 367(9513), 859–869. https://doi.org/10.1016/S0140-6736(06)68079-3

[19]. Mohammad, S., & Iyortim, E. (2013). Application of remote sensing and GIS in flood vulnerability mapping: A case study of Katsina state, Nigeria. International Journal of Water Resources and Environmental Engineering, 5(9), 507–512.

[20]. Nelson, S. A. (2001). Introduction to environmental hazards. McGraw-Hill.

[21]. Nwilo, P. C. (2013). Causes of floods in Nigeria and solutions. Nigerian Institute of Oceanography and Marine Research.

[22]. Ozcan, O., & Musaoglu, N. (2010). Effects of increasing urbanization on surface run-off: Istanbul case study. Environmental Monitoring and Assessment, 166(1), 15–24. https://doi.org/10.1007/s10661-009-0983-9

[23]. Raaijmakers, R., Krywkow, J., & van der Veen, A. (2008). Flood risk perceptions and spatial multi-criteria analysis: An exploratory research for hazard mitigation. Natural Hazards, 46(3), 307–322. https://doi.org/10.1007/s11069-007-9189-z

[24]. Ramirez, J. A., Mendoza, P., & Thai, J. (2016). Enhancing the flood risk assessment in an urban area through reduced-complexity hydrodynamic model coupled with spatial indicators. Environmental Modelling & Software, 79, 105–118. https://doi.org/10.1016/j.envsoft.2015.11.012

[25]. Sampson, C. C., Fewtrell, T. J., Duncan, A., Shaad, K., & Bates, P. D. (2015). Use of reduced-complexity hydraulic modelling in flood risk reduction applications. Environmental Modelling & Software, 69, 221–229. https://doi.org/10.1016/j.envsoft.2014.11.027

[26]. Seto, K. C., Güneralp, B., & Hutyra, L. R. (2011). Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools. Proceedings of the National Academy of Sciences, 109(40), 16083–16088. https://doi.org/10.1073/pnas.1211658109

[27]. Suleiman, R., & Abubakar, I. R. (2014). Flood disasters in Nigeria: Analysis and way forward.

[28]. United Nations. (2015). World urbanization prospects: The 2014 revision. United Nations.

[29]. Van Westen, C. J., & Hofstee, C. (2000). The role of remote sensing and GIS in flood disaster management: Perspectives and experiences from developing countries. In Proceedings of the United Nations/ISDR Workshop on the Use of Space Technology for Disaster Management in Africa.