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Spatial analysis of flood vulnerability levels in Sagbama Local Government Area using geographic information systems (GIS)

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ABSTRACT

This research was aimed at examining geographic information systems (GIS) as a useful and important technique in monitoring flood in Sagbama Local Government Area; by using the Analytical Hierarchical Process (AHP). Flood vulnerability mapping is important and proper monitoring and forecasting of flood helps in proper allocation of the urban land use and to a greater extent gives warnings to the flood prone areas. However, the assessment of flood requires knowledge of flood risk areas in order to develop prevention as well as mitigation measures. Flood risk maps are essential tools in the identification of flood vulnerable areas, thus this paper used this tool in identifying flood vulnerable areas in Sagbama areas of Bayelsa State, Nigeria. The paper among others, recommends a general flood risk mapping of the entire region for flood disaster mitigation planning.

INTRODUCTION

Flood is an extreme naturally occurring weather event that results in an overflowing of large amounts of surface water over land that is not always inundated (Adeoye et al., 2009). Floods are considered to be the worst natural disaster in the world and are responsible for a third of all natural problems and half of the damages on facilities around the globe. It has become one of the most frequent natural occurrences in the last few decades (Jeb and Aggarwal, 2008). Floods have cost damages to societies totaling more than 250 billion dollars and the intensity and frequency of floods are increasing globally. It is gradually becoming a common phenomenon around the world, caused by increased average global temperature that results in torrential rains and rise in sea level which overflowed their banks and flood surrounding coastal lands (Jeb and Aggarwal, 2008). In Nigeria, besides droughts, floods cause almost 90% of damages resulting from natural hazards (Adeoye et al., 2009).

Floods that occur in Nigeria are as a result of extensive rainfall, drainage blockages and dam failures (Jeb and Aggarwal, 2008). The effects of floods in Nigeria have been on the increase especially in the last three decades. It has become a life threatening concern to the citizenry and the number of deaths and damages caused by this perennial disaster are alarming. Annually, more than 7700,000 hectares of arable land and built up areas are damaged due to flooding in Nigeria (Jeb and Aggarwal, 2008). Recorded damages include destruction of schools, houses built with mud brick and other traditional building materials, bridges, markets and agricultural lands (Adeoye et al., 2009). Nigeria recorded its first flood in 1948 in Ibadan, capital of Oyo State. Since then, the occurrence of floods has spread to other states of the nation. More than half of the 36 States in Nigeria have been hit by one form of flood or another (Adeoye et al., 2009) that occur along the Niger and Benue Rivers (Jeb and Aggarwal, 2008). Some of the States that have been badly hit by floods in the country include Kano, Niger, Jigawa, Kaduna, Adamawa, Benue, Kogi and many others in the southern parts of Nigeria (Adeoye et al.,

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2009; Jeb and Aggarwal, 2008). In August 2001, thousands of people were displaced in Kano and Jigawa States as a result of flood that was caused by the overflowing of Challawa and Kano Rivers. Twenty people were reported dead in Kano while 180 people were reported dead in Jigawa State (Jeb and Aggarwal, 2008). A record of the total number of people affected by the flood incidence was well above 143,000 (Jeb and Aggarwal, 2008). The Federal Government of Nigeria has invested millions of dollars both on relief and compensation as well as rehabilitation of flooded areas yet the menace is still unabated (Jeb and Aggarwal, 2008). These days, flood events are more rampant in urban cities in Nigeria than in the rural areas (Ogba et al., 2009). It is fast becoming a serious environmental problem resulting in huge losses of lives, property and priceless arable land.

Floods have rendered many people homeless and disrupted a lot of socio-economic activities in urban cities. Various flood plains and land along the Atlantic Ocean coast are affected by flooding yearly in Nigeria (Jeb and Aggarwal, 2008).

Geographic information systems (GIS) have been used in developing flood risk maps that show vulnerability to flooding in different places around the world (Demessie, 2007; Manandhar, 2010). In developed countries, production of flood risk maps has become important criteria for carrying out some major development interventions (European Commission, 2007). In Nigeria, different studies have been conducted on flood risk assessment and mapping of urban areas as well as coastal plains (Adeaga, 2008; Jeb and Aggarwal, 2008, Ishaya et al., 2009; Ogba et al., 2009; Yahaya et al., 2010). These different researches have assisted in providing some information about floods in Nigeria, but they have not fully assessed flood risks in all the flood prone zones in Nigeria. Due to lack of advanced technological methods for capturing geographical data, limitations exist in researches involving urban centers in Nigeria (Ishaya et al., 2008; Ifatimehin et al., 2009; Ishaya et al., 2009; Ishaya and Ifatimehin, 2009; Ujoh et al., 2011) and flood risk assessments have only been carried out in areas where appropriate data for research can be easily acquired. This study therefore examined GIS as a useful and important technique to monitor flood in Sagbama Local Government Area (LGA). The proper monitoring and forecasting of flood will help in the proper allocation of urban land use and to a greater extent, give warnings to the flood prone areas in the study area which would help to reduce the state of human and infra-structure insecurity in the region to flood.

STUDY AREA

Sagbama LGA is one of the oldest LGA in Bayelsa State. It was created in 1976 with headquarters at Sagbama town. Sagbama LGA is located between longitude 8.1-6.4° N and latitude 7.20-7.3° E. It has an area of 945 km² and a population of 21,448 according to 2006 census. The LGA shares boundary with Ekeremor, Kolokuma/ Opokuma, Yenagoa, Southern Ijaw LGAs in Bayelsa State and Patani LGA of Delta State (Figure 1). Sagbama LGA is made up of the Ijaw, Isoko and Urhobo ethnic nationalities. The Ijaws are dominant, making over 90% of the total population.

The study area enjoys a tropical monsoon climate with lengthy and heavy rainy seasons from April to October ranging from 2000 to 2500 mm and short dry seasons. The temperature is high all around the year with a relatively constant high humidity.

There is high influx of people into the area resulting in rapid increase in the population of the study area. This is due partly to the relocation of higher institutions like the Isaac Boro College of Education, Government Teacher's Training Institute and a campus of the Niger Delta University. The soil is sandy-loam underlain by a layer of impervious pan and is always leached due to the heavy rainfall experienced in this area. The study area is well drained with both fresh and salt water. The salt water is caused by the intrusion of sea water inland. The relief is generally lowland. The vegetation found in this area includes raffia palms, thick mangrove forest and light rain forest.

MATERIALS AND METHODS

Sources of data

The primary data used for this study were obtained from four sources. The data includes topographical map of scale 1: 100000 obtained from the Bayelsa State Ministry of Lands and Housing; satellite imagery of the study area, obtained from Google earth, 2013 version. Contour, communities and drainage were derived from the topographical map and land use map was derived from the imagery. The topographical map of scale 1: 100000 was scanned and imported to ArcView GIS 3.3 version whereby it was geo-referenced to geographic coordinate and thereafter the contour lines were digitized. The imagery was also geo-referenced and the land use types were captured and labeled into built-up areas, water body, derived forest, and farmland. From the contour map, point data having the X, Y and Z coordinates were generated. The X (Eastings) and Y (Northings) coordinates were generated from script avenue (an extension program in ArcView GIS) while the Z (Height) values were the contour values. All the shape files (that is, contour, point data, land use, drainage) were imported to ArcGIS 9.2 environment whereby further analyses were performed. The point data were used to generate digital

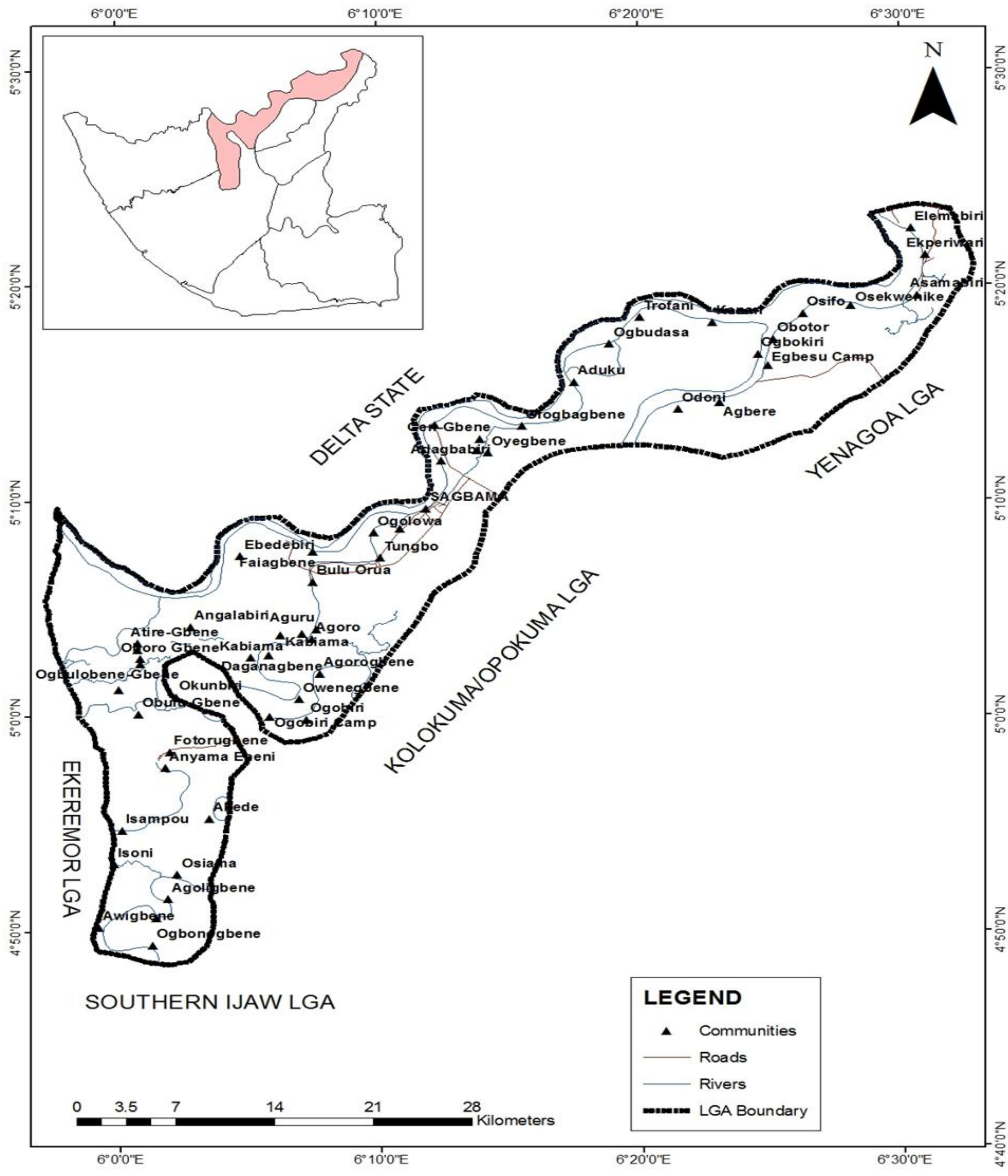

Figure 1. Map of Sagbama Local Government Area.
Source: Bayelsa State Ministry of Lands and Survey and Google Earth, 2013.

elevation model (DEM) through interpolation method called Kriging. This shows the varying elevations of the Port Harcourt metropolis. This study considered DEM (elevation), residential densities, land use types and drainage as the parameters used to generate flood vulnerability mapping in the study area because the study employed the Analytical Hierarchical Process (AHP).

AHP is a multi-criteria decision making technique, which provides a systematic approach for assessing and integrating the impacts of various factors, involving several levels of dependent or independent, qualitative as well as quantitative information (Bapalu and Sinha, 2006). It is a methodology used to systematically evaluate, often conflicting, qualitative criteria (Saaty, 1980 cited in Bapalu and Sinha, 2006). AHP is like other multi-attribute decision models, like Multi-attribute Utility Theory (MAUT), Bayesian Team Support, Ad-hoc decision making which attempt to resolve conflicts and analyze judgments through a process of determining the relative importance of a set of activities or criteria by pairwise comparison of these criteria on a 9-point scale (Bapalu and Sinha, 2006).

AHP is often used to compare the relative preferences of a small number of alternatives concerning an overall goal. AHP is now popular in decision-making studies where many factors are considered (Bapalu and Sinha, 2006). Therefore, each of the parameters was reclassified into three which included highly vulnerable, moderately vulnerable and lowly vulnerable through the ranking process or weight rating. Flood vulnerability map (FVM) was later generated by overlaying the reclassified maps of all the parameters using addition operator to generate the vulnerability or flood risk map of Sagbama LGA.

RESULTS AND DISCUSSION

Reclassification based on Digital Elevation Model of Sagbama Local Government Area

The DEM or surface analysis of Sagbama LGA revealed that the relief fall within the range of 7 and 30.7 m. Communities like Akede, Angalabiri and Sagbama are on elevation of 7.0-17.8 m while places like Agoro, Bagbene and Tungbo are between 17.9-22.2 m. Some areas like Asamabiri, Elemebiri and Foturogbene are above 22.2 m. This shows that different communities are situated at different elevation. The whole study area was reclassified into different vulnerability capacities based on the elevation map. The area between 7.0 and 17.8 m was classified as highly vulnerable, areas between 17.9 and 22.2 m were classified as moderately vulnerable while areas above 22.2 m were classified as lowly vulnerable areas. Figure 2 shows that the whole area was delineated into three vulnerability levels. Communities like Asamabiri, Elemebiri, Foturogbene etc. are lowly vulnerable while communities like Aduku, Agoro, Bagbene and Tungbo etc. are moderately vulnerable. However, very large areas occupied by Adagbabiri, Angalabiri, Osifo, Sagbama, etc. communities are highly vulnerable.

Reclassification based on the drainage (RD)

The communities were rated based on their proximity to the rivers and seas in the study area. This helps in classify the whole study area into three, namely; highly vulnerable, moderately vulnerable and lowly vulnerable. Humans and facilities within 500 m proximity to water bodies are regarded as higly vulnerable, those within 1000 m moderately vulnerable and those within 1500 m lowly vulnerable. The map shows that majority of the study area are both highly and moderately vulnerable to flood while the spatial extent that is lowly vulnerable is very small.

Reclassification based on land use types

Figure 3 shows that there are five land use types in the study area and they are: Built up area, developing area, sparse vegetation, thick vegetation and water body. Thick vegetation occupied about two-third of the entire study area. The land use was later reclassified into three based on the capacity of each land use type to infiltrate water. The built up area, developing area and water body are highly vulnerable, sparse vegetations are moderately vulnerable while the thick vegetations are lowly vulnerable. With reclassification analysis on the land use map, two-thirds of the entire area is classified to be lowly vulnerable to flood while very small area is highly vulnerable to flood.

Flood vulnerability mapping (FVM) of Sagbama Local Government Area

This study employed overlaying operation using addition operator to reclassified drainage, land use and DEM. The analysis revealed that communities like Adagbabiri, Aduku, Bulu, Orua, Osiama, Sagbama, etc, are very highly vulnerable to flood while communities like Agbere, Agoro, Asamabiri, Elemebiri, Tungbo, etc, are highly vulnerable. Communities like Angalabiri, Ebedebiri, Kabiama etc. are moderately vulnerable to flood while communities like Kenan, Oborogbene, Borutugbene are lowly vulnerable as shown in Figure 4.

Quantitatively, the analysis of Sagbama LGAs' vulnerability to the risk of flood shows that the very highly vulnerable places covered 177.11 square kilometers with

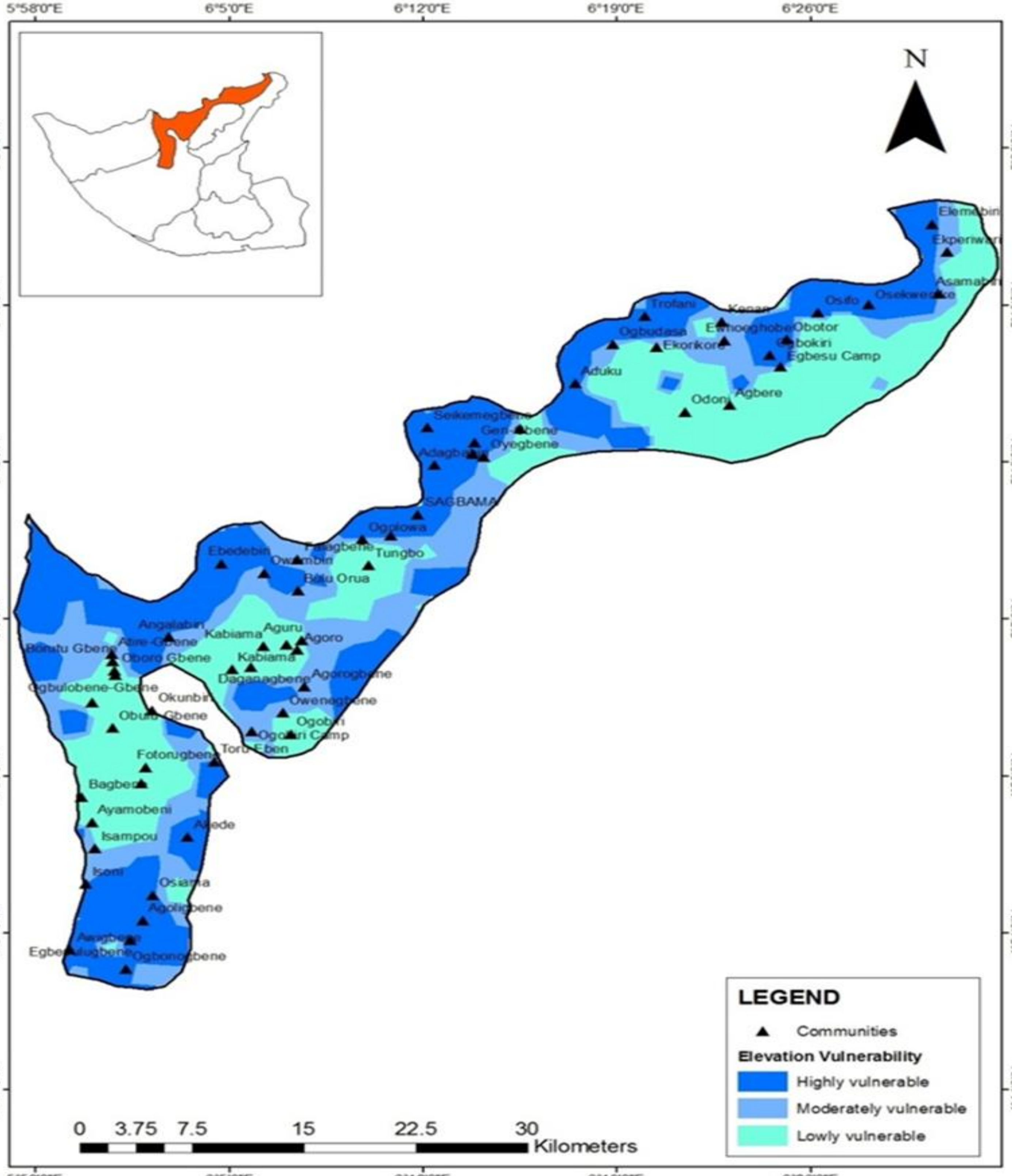

Figure 2. Flood vulnerability map on the bases of elevation in Sagbama Local Government Area.

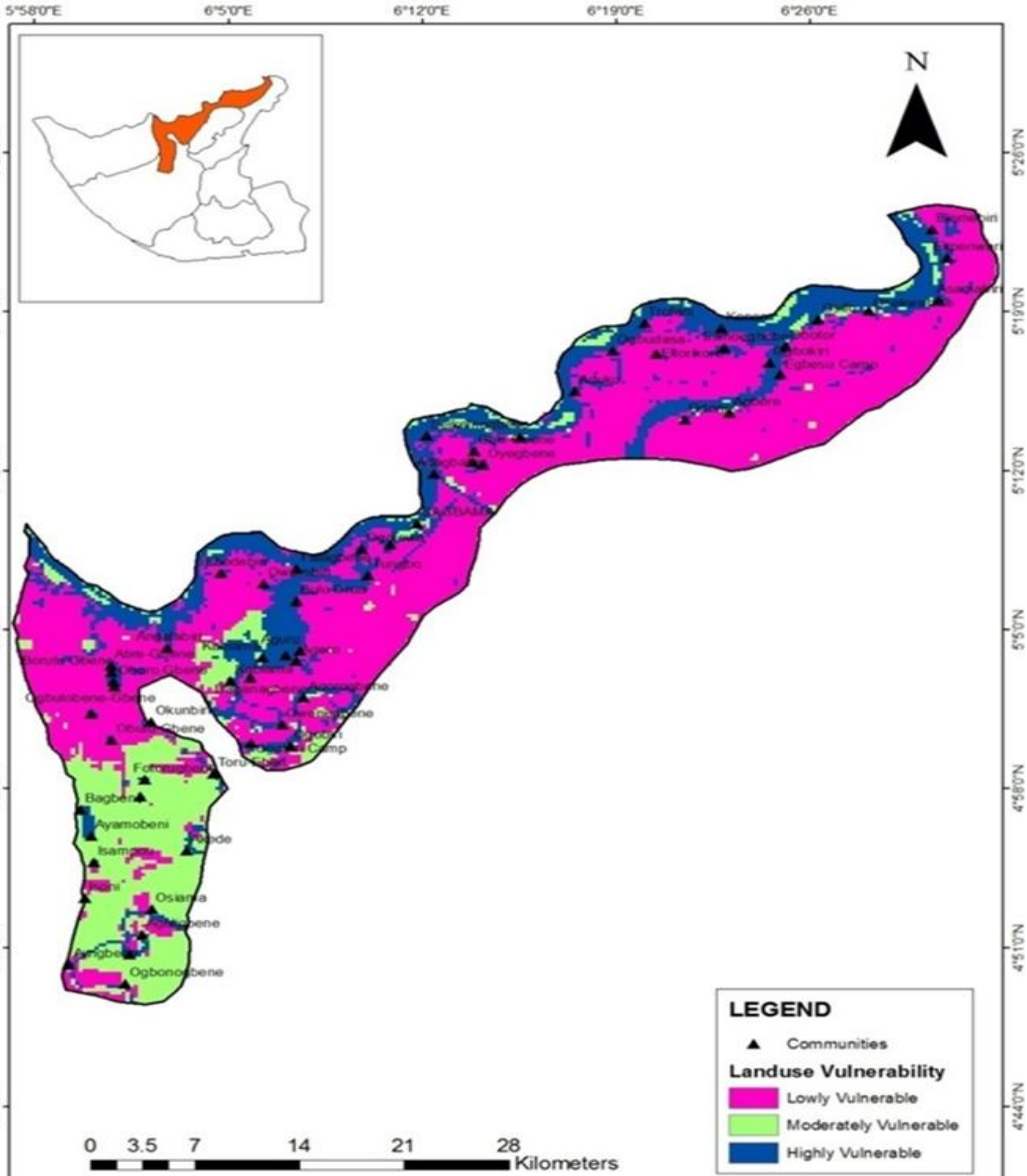

Figure 3. Flood vulnerability map on the bases of land use in Sagbama Local Government Area.

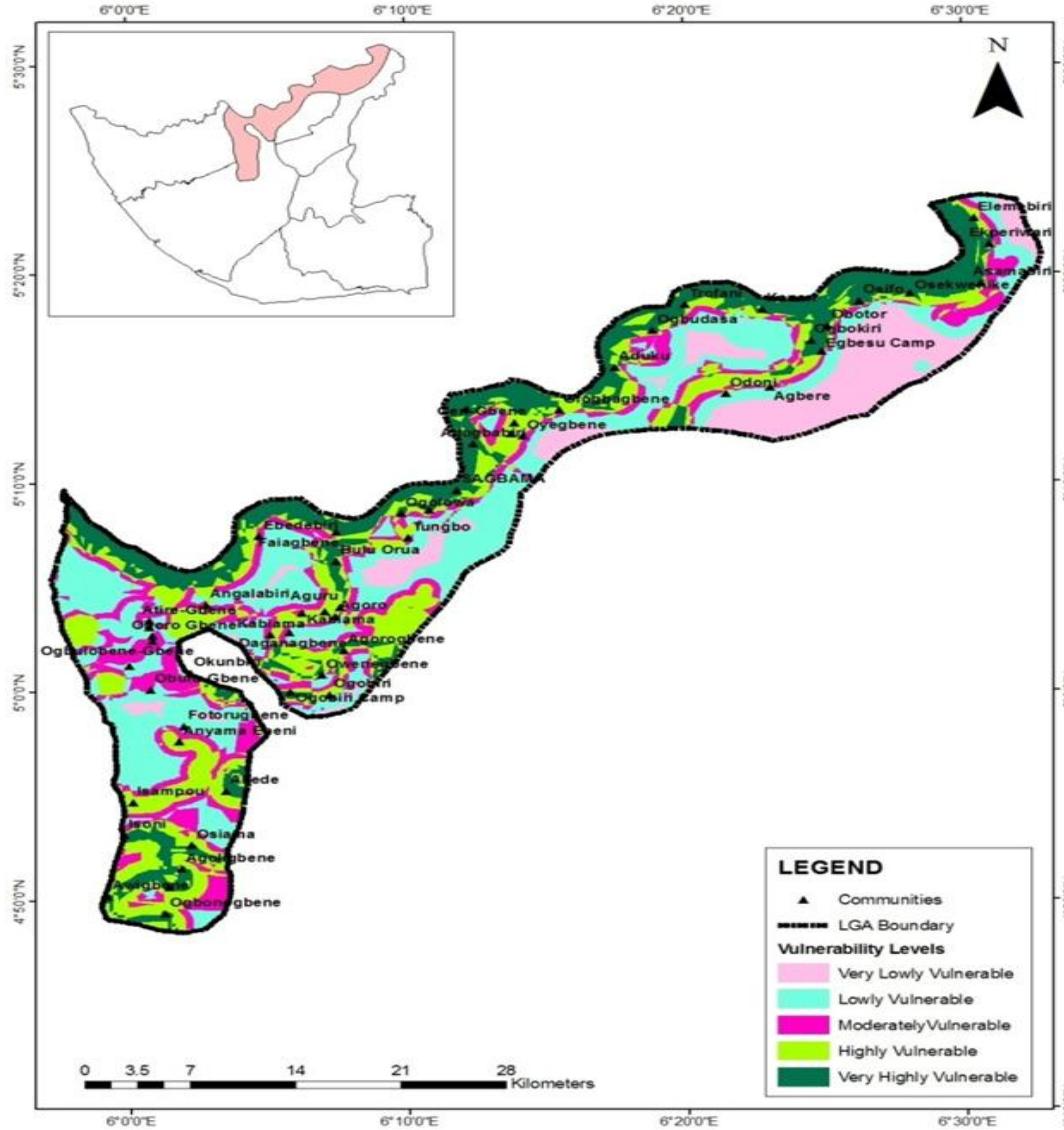

Figure 4. Flood vulnerability map for Sagbama Local Government Area.

21 communities; highly vulnerable areas covered 210.71 square kilometers with 21 communities, while the moderately vulnerable places covered 154.25 square kilometers with 7 communities. The lowly vulnerable areas covered 284.34 square kilometers with 5 communities while very lowly vulnerable areas covered 129.68 square kilometers with no community. The analysis therefore revealed that the total area in square kilometers vulnerable to flood in Sagbama LGA is 542.07 square kilometers with 49 communities at risk of being

flooded.

CONCLUSION AND RECOMMENDATIONS

This study has demonstrated the use of AHP technique with GIS-based overlay analysis to determine spatial flood vulnerability levels in Sagbama LGA whereby different factors have been considered. The study revealed that on the bases of closeness to rivers, pattern of land use, low relief, and drainage; some areas like Adagbabiri, Aduku, Bulu Orua, Osiama, Sagbama, etc, are very highly vulnerable to flood while communities like Agbere, Agoro, Asamabiri Elemebiri, Tungbo, etc, are highly vulnerable. Communities like Angalabiri, Ebedebiri, Kabiama, etc, are moderately vulnerable while communities like Kenan, Oborogbene and Borutugbene are lowly vulnerable to flood. From the results obtained, GIS has revealed flood vulnerability levels in Sagbama LGA. It is therefore recommended that flood plain habitation be discouraged. Also, in the construction of social infrastructures and facilities, previous flood benchmarks should be noted and constructions should be done on elevations that are sustainable. In addition, there is need for high resolution digital elevation data and imageries; and microwave remote sensing during flooding which would be useful in assessing damages and support post-disaster management. Finally, the paper recommends a general flood risk mapping of the entire region for flood disaster mitigation planning.

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