FLOOD VULNERABILITY ASSESSMENT OF AFIKPO SOUTH LOCAL GOVERNMENT AREA, EBONYI STATE, NIGERIA

ABSTRACT

The study was conducted in Afikpo South Local Government covering a total area of 331.5km^2. Remote sensing and Geographic Information System (GIS) were integrated with multicriteria analysis to delineate the flood vulnerable areas. Seven criteria were considered; rainfall, runoff, slope, distance to drainage, drainage density, landuse and landcover, and soil. The various criteria were fit into fuzzy membership classes based on their effect in causing flood. The fuzzy members of all criteria were then overlaid to generate the flood vulnerability map. The result of the flood vulnerability map shows that very low vulnerable zones cover 86.7% of the total area, low vulnerable zones cover 1.6% of the total area, moderate vulnerable zones cover 2.17% of the total area, highly vulnerable zones cover 2.3% of the total area while very highly vulnerable zones cover 7.3% of the total area. Built up was used as a measure of the effect of flooding on human lives and properties in Afikpo South Local Government. Built up covers a total area of 38.6km^2. Over sixty eight (69.8%) of built up lies in very low vulnerable zone, 3% lies in low vulnerable zone, 3.7% lies in moderate vulnerable zone, 0.6% lies in highly vulnerable zone and 17.9% lies in very highly vulnerable zone. The study provides information on target areas that may be affected by flood in Afikpo South Local Government. This information is useful for decision making on flood early warning and preparedness as well as in mitigation preparedness within Afikpo LGA.

Keywords: Flooding, Vulnerability Assessment, Ebonyi State, Multicriteria Analysis, Nigeria

1. INTRODUCTION

Vulnerability can be defined as the degree of loss resulting from the occurrence of a natural or manmade phenomenon of a given magnitude to a known environmental constituent or set of environmental constituents said to be at risk [18]. It is expressed on a scale from 0 (no damage) to 1 (total loss). The location of the areas where the largest economical losses due to natural or manmade disasters could occur is of invaluable importance to urban planning. Therefore, there is a need to complement natural hazard studies with vulnerability and risk assessments. Such study could serve the purpose of early warning or total prevention of locating viable economic activities to the areas where they are vulnerable.

Increasing number of natural disasters of which flooding is the greatest and most common is being reported on major news media all around the world as causing great damages on existing infrastructures in urban areas. In April 2013 at Cook County (Illinois), USA, critical facility that supplied power for a major international airport was inundated by catastrophic flooding just 4 inches away from the point of causing potential disaster. Hurricane Sandy's impact in 2012 on the East Coast of Illinois proved that there is a need for infrastructural preparedness and critical examination of critical facilities across major U.S. cities. According to [1] Iran has suffered from a loss of over $ 3.7 billion as a result of flooding particularly along the southern shore of the Caspian Sea and in the northern and northeastern Iran. As reported by Safaripour *et al.*, [2] in August 2001, flood killed 210 people and cost $31 million in damage. During 2002-11, there were also dangerous and smaller floods at the same places, which led to a loss of $65 million and the deaths of 28 people [2]

The increase in the rate of flooding across the world in recent times has been alarming. About 70 million people across the globe are exposed to flood every year and more than 800 million are living in flood prone lands [3]. Flooding is caused by heavy rainfall or when rivers overflow their banks and submerge dry lands or dam failure [4]. Flood triggered by torrential rainfall have killed dozens across the world. Increase in flood magnitude and frequency has been related to climate change coupled with increasing population growth and urbanisation [5]. The current trend and future scenarios of flood risk requires that accurate spatial and temporal information on potential hazards and risk of floods be carried out [6]. Flood risk analysis provides a rational basis for prioritizing resources and management actions majorly in flood vulnerable areas [7]. Floods have consequences on the economy, environment, human health and cultural heritage. Economic assessment of flood risk is simply about calculating the average annual costs of damages or loss. Economic assessment of flood risk management measures is about balancing the reduction of annual damage cost against the average annual cost of risk reduction measures over their lifetime [8].

In Nigeria, recent flooding has left both the government and the governed devastated [9]. Flood displaces more people and causes damages to properties and infrastructures than any other natural disaster in Nigeria [10]. In 2012, it was recorded that Nigeria suffered a loss of more than $16.9b in damaged properties, oil production, agricultural and other losses due to flood disaster. Increase in flood occurrence coupled with lack of coping capacity and high levels of vulnerability of the populace have continued to put many lives and properties at risk in Nigeria [11]. While reliable infrastructures is vital to human needs, currrent urbanisation trends in the country are defining negative regards to flood vulnerability. Of particular concern is the fact that the impoverished part of the population who are most likely to settle in flood risk zones are the least able to adopt measures for adaptation during flood disasters [12]

In Nigeria, several scientists at different times have studied flood risk and vulnerability assessment. Nkeki *et al.,* [13] using the moderate resolution imaging Spectroradiometre (MODIS) data of NASA Terra satellite reported that geospatial methods are powerful techniques in mitigating and monitoring the effect of flooding along the Niger-Benue basin. Ojeh and Victor-Orivo [14] reported heavy inundation of farmlands soon after a heavy rainfall in Odah, Iwhre-otah and Erorin communities in Oleh, Isoko area of Delta State in the Niger Delta area of Nigeria led to loss of 0.608 kilometers farmland at Odah, 0.441 kilometers at Iwhreotah, 0.547 kilometers at Erorin in 2011 and 0.485 kilometers at Odah, 0.425 kilometers at Iwhreotah and 0.598 kilometers in 2012 respectively. Their study revealed that all the crops cultivated in the area (cassava, melon, yam, maize, plantain) were affected by flooding above 50 percent of total yield of each crop cultivated in the area except yam (46.9%).

Okwu-Delunzu *et al.,* [15] using Google image and Shuttle Radar Topography Mission (SRTM) of 2012 in Anambra East and environs, Nigeria discovered that 71% of the study area was liable to flooding of which farmlands account for 41.7% of the landuse. Olajire *et al.,* [16] observed from their study of the Ala river basin, Akure, Ondo state using geographical information system integrated with fuzzy logic that the causative factors of flood within the basin were slope, distance to drainage, drainage density, soil type and land use.

In the Nigerian newspapers and magazines, Afikpo south has always been part of communities mentioned yearly as part of flood prone areas. Torrential rainfall is the cause of flooding in this area. The flood ravages farmland, human lives and properties. In some places houses are submerged by water. The flooding in these areas is usually triggered by overflow of Obubra river in Cross River State and Akpoha river in Ebonyi State. Little has been done by the state government to mitigate flooding in Afikpo South Local Government, even with the yearly flood early warning from the Nigerian Meteorological Agency (NIMET) and National Emergency Management Agency (NEMA). Given that floods continue to cause yearly significant human, material and infrastructural damages in Afikpo South Local Government of Ebonyi State, flood risk mitigation is a key issue and the first step is to identify risk areas for effective flood management planning. There are various ways of measuring the impact of flooding in terms of the social, economic, environmental and geographical effects. This study takes into consideration the geographical dimension of flood impact in the study area. The aim of this study is to evaluate the spatial extent of flood risk in Afikpo South Local Government of Ebonyi State. Olajire *et al.,* [16] posited that one way to mitigate the effects of flood is to ensure that all areas that are vulnerable are identified and adequate precautionary measures taken to ensure adequate preparedness, effective response, quick recovery and effective prevention.

2 MATERIALS AND METHODS

2.1 STUDY AREA

Afikpo South Local Government Area (LGA) is located between longitude 7^{o} 40' E to 7^{o} 53' E and latitude 5^{o} 41' N to 5^{o} 57' N (Fig 1). Afikpo South is historically known as Edda. It is the homeland of Edda people, an Igbo subgroup. Its administrative headquarters is at Nguzu Edda. Edda is Bordered by Unwana to the east, Akaeze to the west, Ohafia to the south and Amasiri to the north. The basic occupations of people in the LGA are farming and fishing.

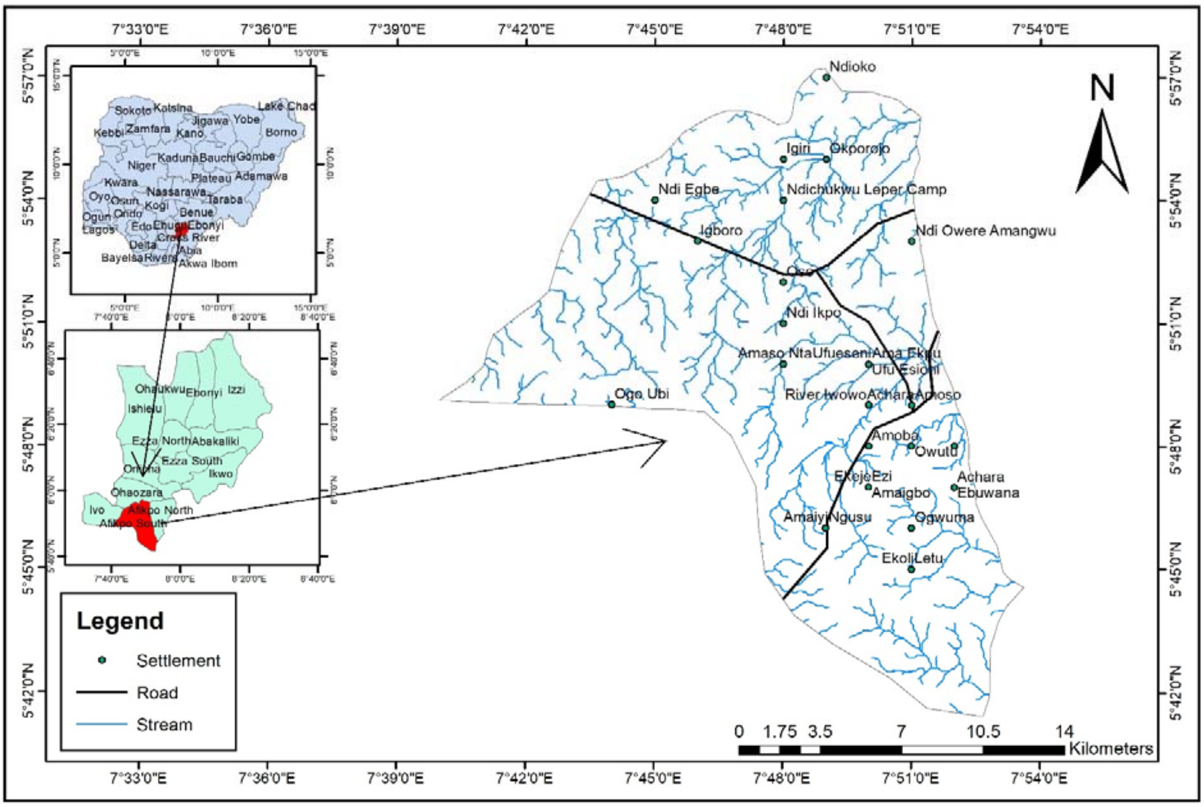

Fig 1. Map of Afikpo: Study Location

Afikpo South LGA cover a total of 330km^2 in area with a population of 157,072 according to the 2006 Nigeria population census. The climate is characterized by two distinct seasons; the dry and rainy season. The rainy season is oppressive and overcast. The dry season is muggy and mostly cloudy. According to Koppen and Geiger, the climate of Afikpo is classified as **Aw** with average temperature of 27.2°C and average annual rainfall of 2022mm. Afikpo South landscape features lush vegetation with parklands and short trees added to a litter of woodlands and forests.

2.2 METHODOLOGY

Shuttle Radar Topography Mission (SRTM) satellite imagery was acquired from the United State Geological Survey (USGS) website. The data was used to delineate the stream network and slope of the study area using surface analysis and hydrology analysis tool in ArcGIS software. The generated stream network was then used to calculate the drainage density and distance to drainage. The distance to stream was calculated using spatial analysis tool. Drainage density was generated using the line density tool. Soil data were extracted from the Harmonised World Soil Database (HWSD) by Food Agriculture Organisation (FAO). The data was georeferenced and digitised. It was converted to a raster format for further analysis. The raster soil map was then reclassified.

Gridded rainfall and runoff data were acquired from ERA-Interim for the period of 30years. The data covered a period of 1986 – 2015. The gridded data were interpolated to model rainfall and runoff within the study area. The gridded data were interpolated using the Inverse Distance Weighting method to generate the spatial distribution of rainfall and runoff over the study area.

Landsat 8 Operational Land Imager (OLI) Imagery path 188 and row 056 for 17th of January 2015 was acquired from the United States Geological Survey's (USGS) website for the study area. The imagery was used to generate the landuse and landcover map of the study area using supervised classification.

The various criteria were put into a fuzzy membership class based on their effect in causing flood. The multivariate analysis tool in ArcGIS was used to create a fuzzy membership class for the criteria. Fuzzy membership set values of criteria that enhance flooding as 1 and values that do not support flooding as 0. Parameters set to 0 do not support flooding while those set as 1 enhance flooding. The fuzzy members of all criteria were then overlaid using fuzzy overlay technique to generate the flood risk map. Fuzzy overlay techniques addresses inaccuracies in attribute and geometry of input dataset. It models the inaccuracies of class boundary. It addresses situations in which boundary between classes are not clear. Fuzzy Logic overlay define possibilities and not probabilities [17]. The fuzzy overlay combines all the sets of 0 and 1 in all input criteria uisng Logic and generates a final map which was reclassified using the classify tool in ArcGIS software into very low, low, moderate, high and very high.

3 RESULTS AND DISCUSSION

Slope

The terrain of an area affects the occurrence of flood in a locality. Figure 2 shows the elevation map of the study area. Slope is the major terrain factor that contributes to flooding. Slope tend to affect the direction of flow of surface runoff. Surface runoff flows from steep slope and gathers in flat areas thereby causing flood in the low-lying zones. Figure 3 shows the slope of Afikpo South Local Government. Slope of $0^{o} – 5^{o}$ are flat/almost flat areas and they are highly prone to flood. Slope of $10^{o} – 15^{o}$ are gentle and are less prone to flood and slope greater than 15^{o} are not prone to flood.

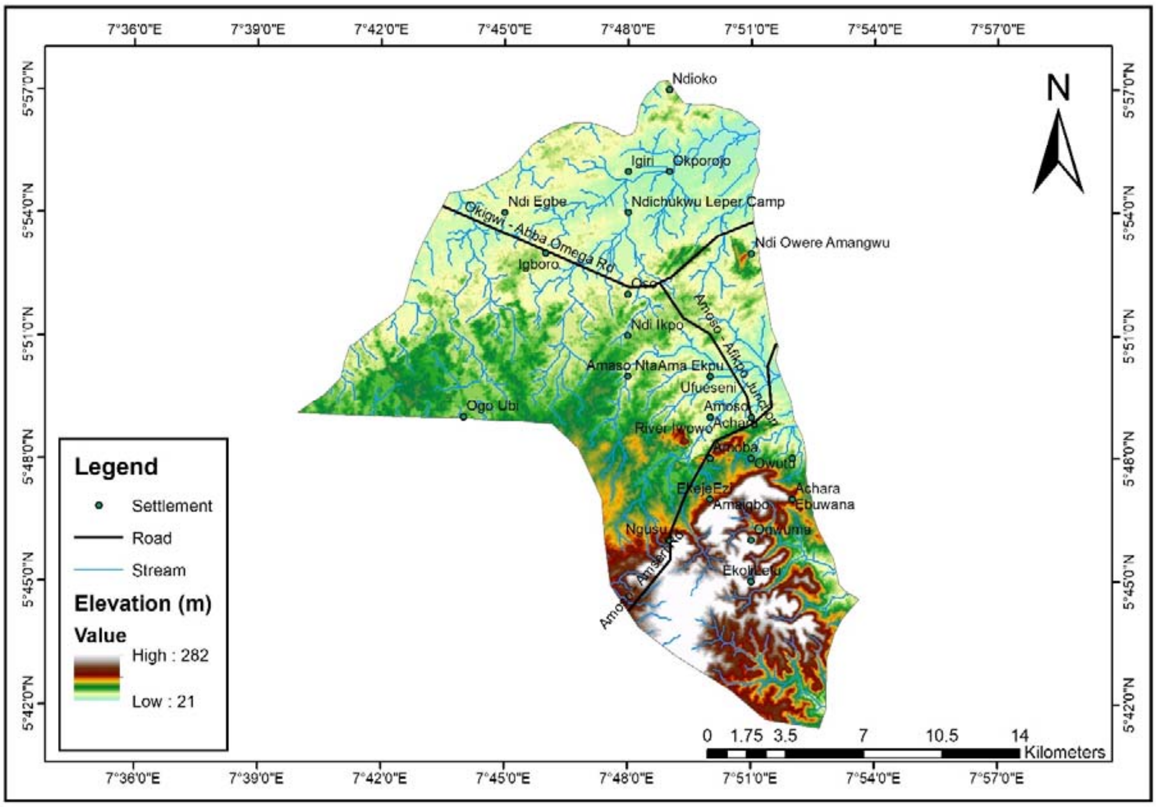

Figure 2: Elevation Map of Afikpo South LGA, Ebonyi State

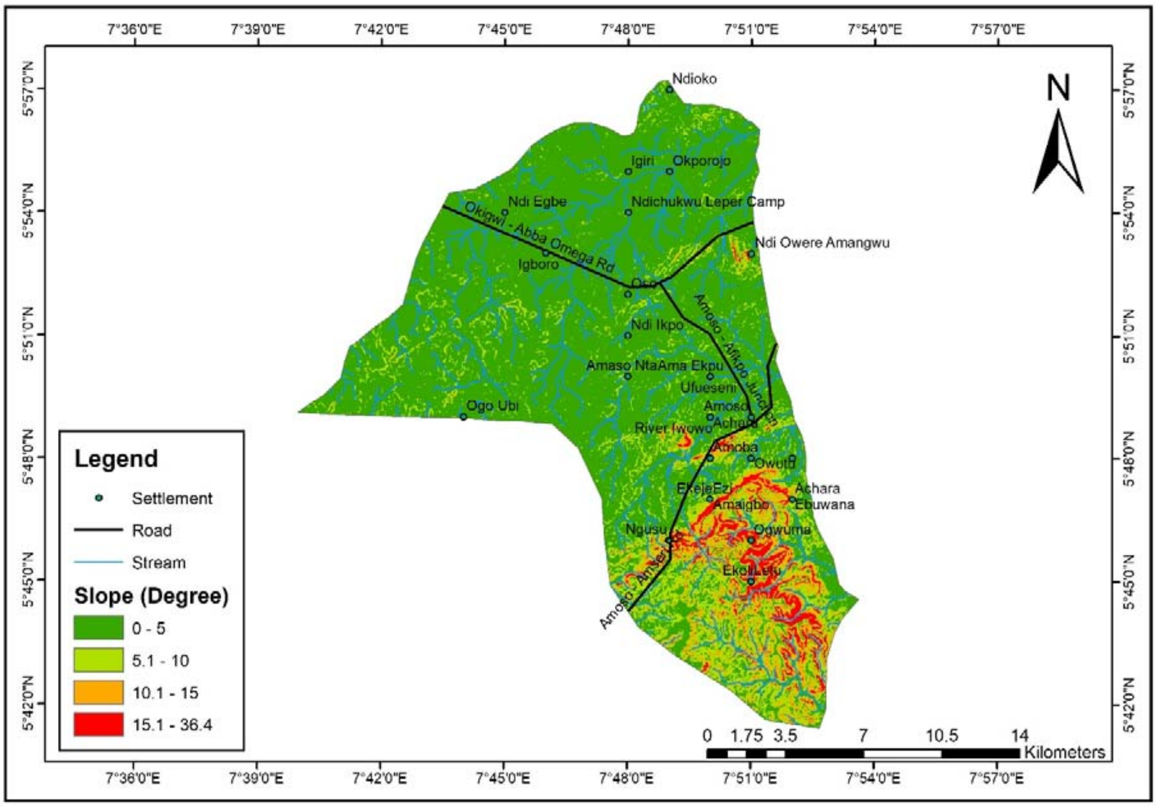

Figure 2: Slope Map of Afikpo South LGA, Ebonyi State

Rainfall

Intense rainfall is the major causes of flood. Places with high rainfall are more susceptible to flooding. Rainfall average for 30 years with in the study area ranges from 170.9mm – 194.1mm. The southern part of Afikpo South Local Government has more rainfall and reduces moving northwards. Figure 3 shows the rainfall distribution map for Afikpo South Local Government.

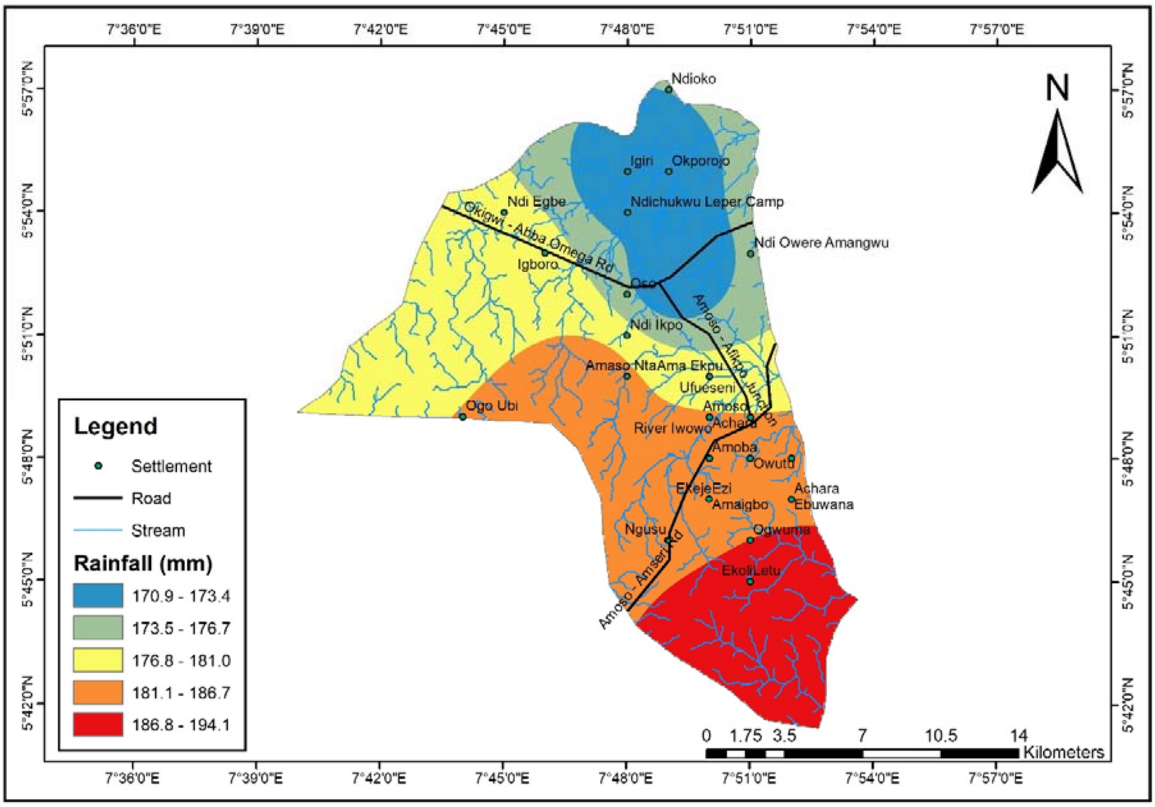

Figure 3: Map of Rainfall Distribution in Afikpo South, Ebonyi State

Runoff

Surface runoff flows from steep slope areas and gathers in low lying areas. Accumulation of surface runoff water in low lying areas is what causes flood. Runoff distribution within the study area for a period of 30 years on the average ranges from 3.12 mm – 3.51 mm. surface runoff are more in the southern parts of Afikpo South Local Government and decreases northwards. Figure 4 shows the surface runoff distribution map for Afikpo South local Government.

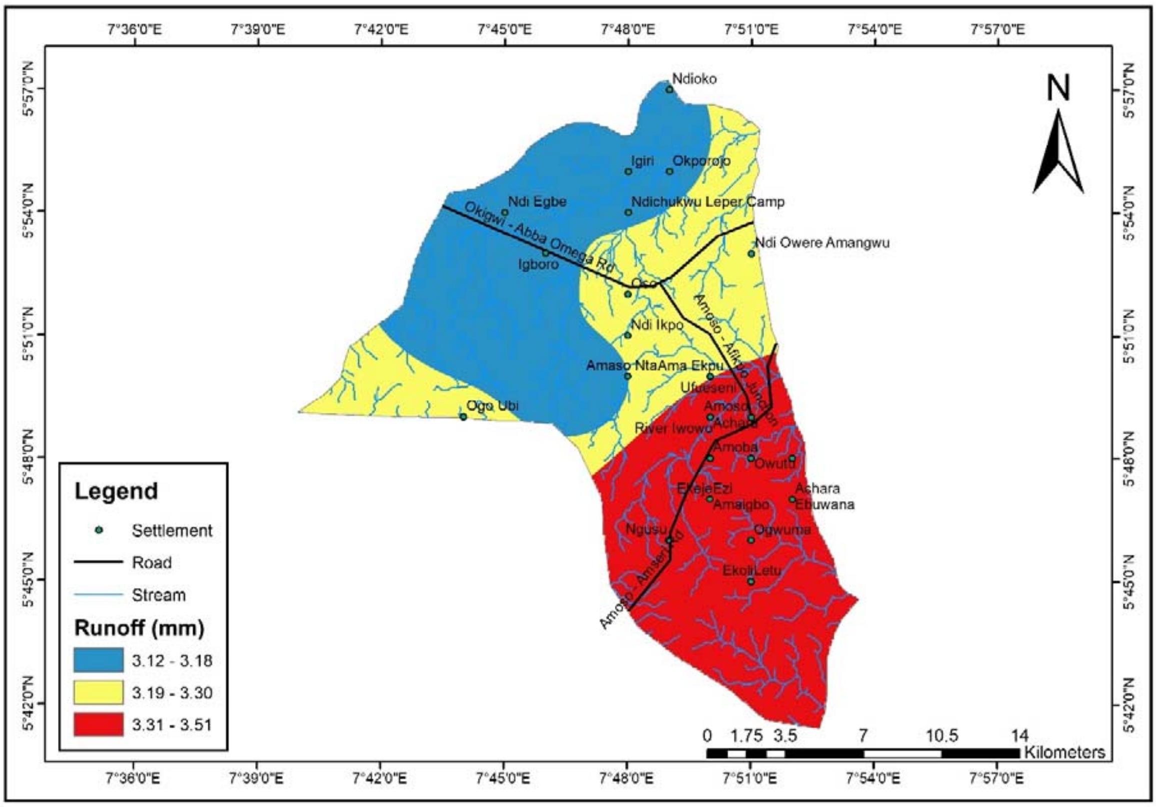

Figure 4: Map of Surface Runoff in Afikpo South, Ebonyi State

Distance to Drainage

Rivers tend to overflow their banks after an intensive rainfall. The overflow of river water enters into dry land thereby affecting all objects on its course which includes lives, properties and infrastructures. Nigeria Town and Regional Planning Regulation of 1986 states that buildings must be at least 30m away from major water channels [16]. Settlements within 30m distance from drainage are highly prone to flood, those within distances of 30m – 150m are less prone to flood and those at distances greater than 150m are not prone to flood. Figure 5 shows the distance to drainage map of Afikpo South Local Government.

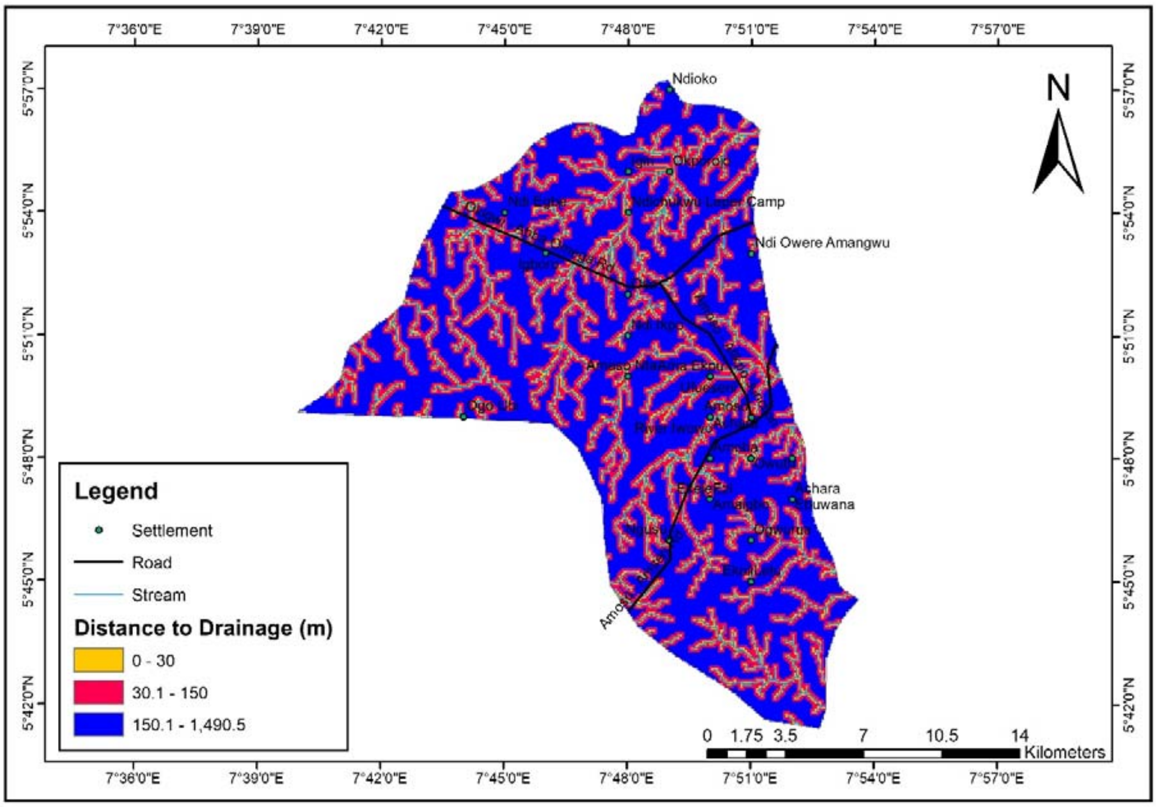

Figure 5: Distance to drainage Map of Afikpo South, Ebonyi State

Drainage Density

Flood occurs at points where river tributaries meets. The more drainage tributaries that meets at a point on a river course, the denser flow of water becomes and the more likely the rivers overflow their banks at this point thereby causing flood. Figure 6 shows the drainage density map of Afikpo South Local government. The drainage density was classified into three; low, moderate and high.

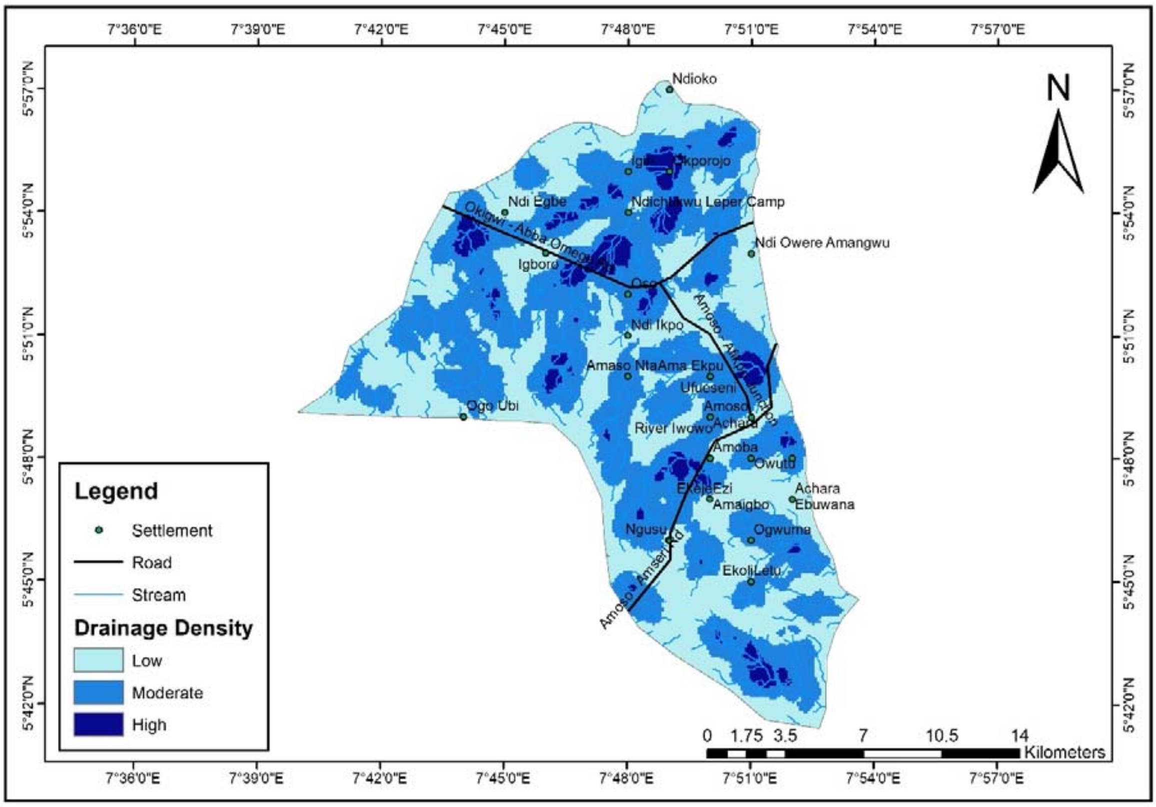

Figure 6: Drainage Density Map of Afikpo South, Ebonyi State

Landuse and Landcover

Figure 7 shows the land use and land cover map of Afikpo South Local Government. Four land use and land cover types were identified; built-up, light vegetation, dense vegetation and wetland. The built-up areas are highly prone to flood as there is a direct impact on human lives, properties and infrastructures. Light vegetation is also prone to flood as they include farmlands, pastures, grasslands and derived Savannahs which are also of economic importance.

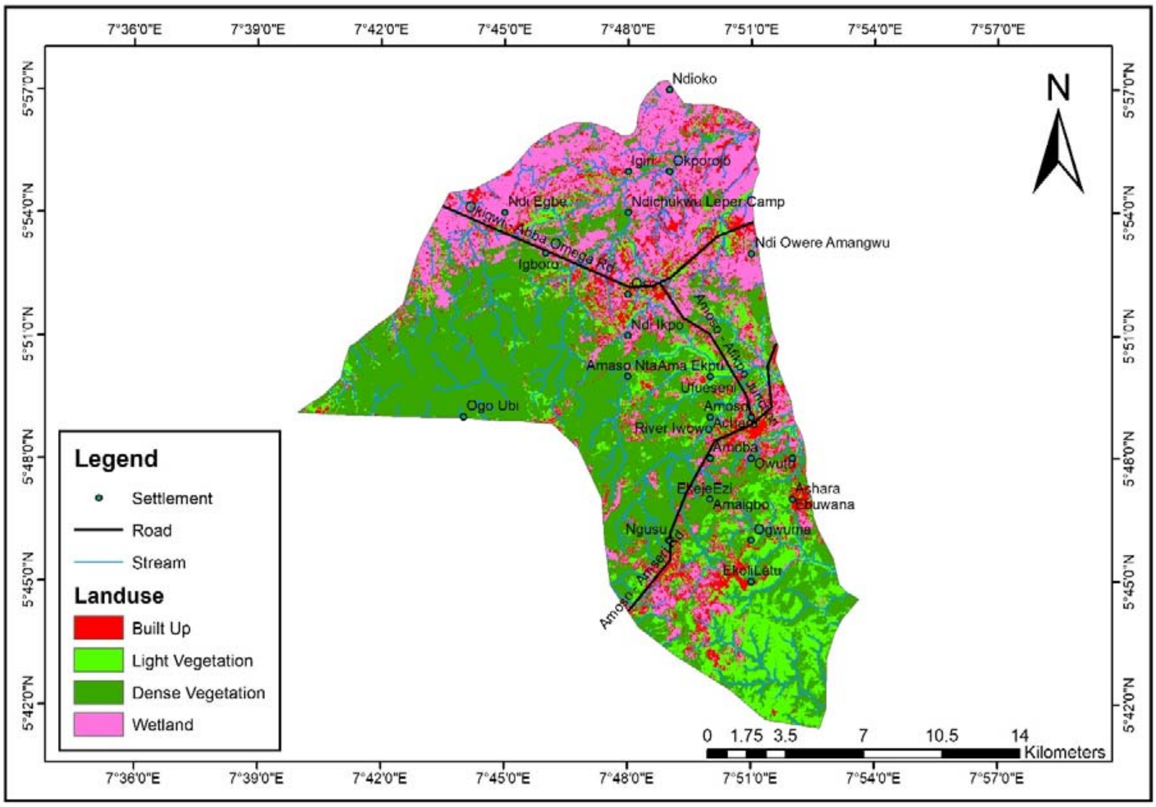

Figure 7: Landcover/Landuse map of Afikpo South, Ebonyi State

Soil

Figure 8 shows the soil map of Afikpo South Local Government. Two soil types were identified within the study area; dystric gleysols and dystric nitosols. The soils were classified based on their drainage properties. Dystric nitosols are moderately well drained which would cause less flood. Dystric gleysols are poorly drained thereby causing flood. A major part of Afikpo South Local Government is covered with dystric nitosols.

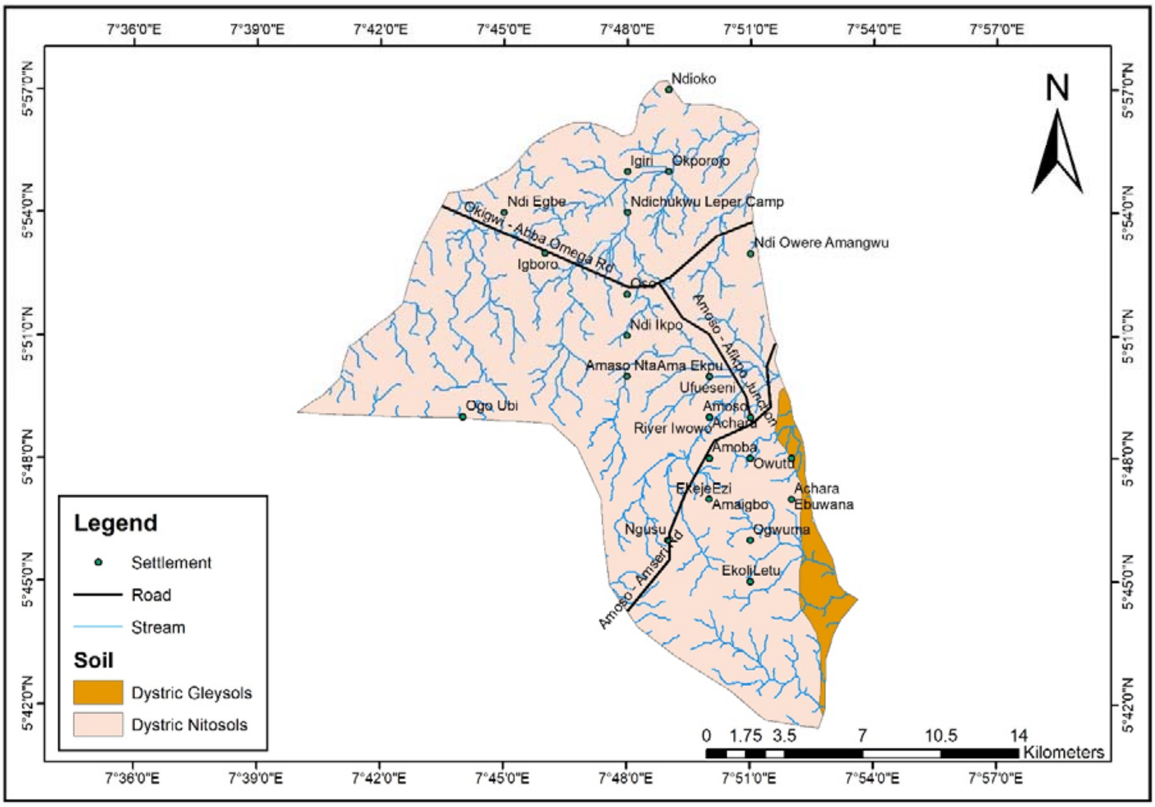

Figure 8: Soil Map of Afikpo South, Ebonyi State

Flood Vulnerability

All criteria were overlaid using fuzzy overlay to delineate the flood vulnerability in Afikpo South Local Government. The flood vulnerability was classified into five; very low, low, moderate, high and very high. Figure 9 shows the flood vulnerability map for Afikpo South Local Government. Afikpo South Local Government covers an area of 331.5 km^2. Very low vulnerable zones cover an area of 287.28 km^2, low vulnerable zone cover an area of 5.18 km^2, moderately vulnerable zones cover an area of 7.18 km^2, highly vulnerable zones cover an area of 7.73 km^2 and very highly vulnerable zone covers an area of 24.13 km^2. The Built-up areas affected are a measure of the effect of flood on human lives and properties. The Built up area covers a total of 38.6 km^2. Built up within very low vulnerable zones cover an area of 26.96 km^2, built up in low vulnerable zones cover an area of 1.17 km^2, built up in moderately vulnerable zones cover an area of 1.43 km^2, built up in highly vulnerable zones cover an area of 1.86 km^2 and built up in very highly vulnerable zones cover an area of 6.91 km^2. Figure 10 shows the built-up vulnerability map.

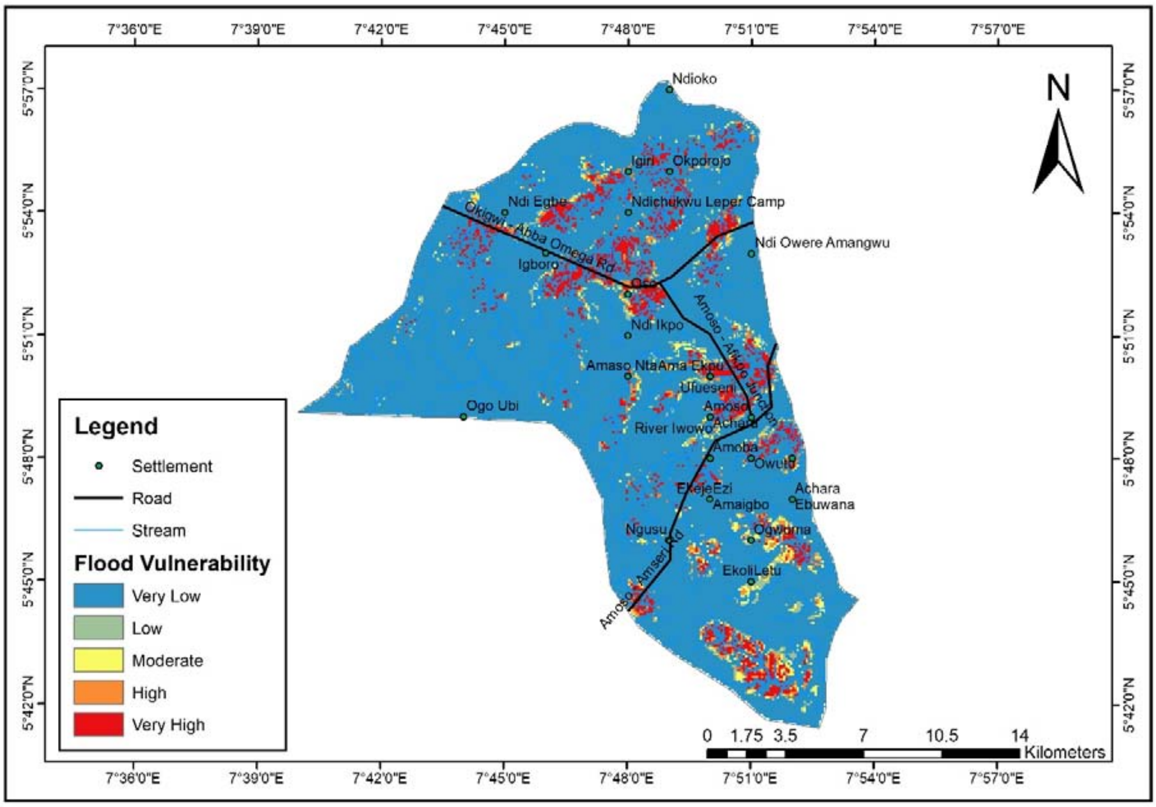

Figure 9: Flood Vulnerability Map of Afikpo South, Ebonyi State

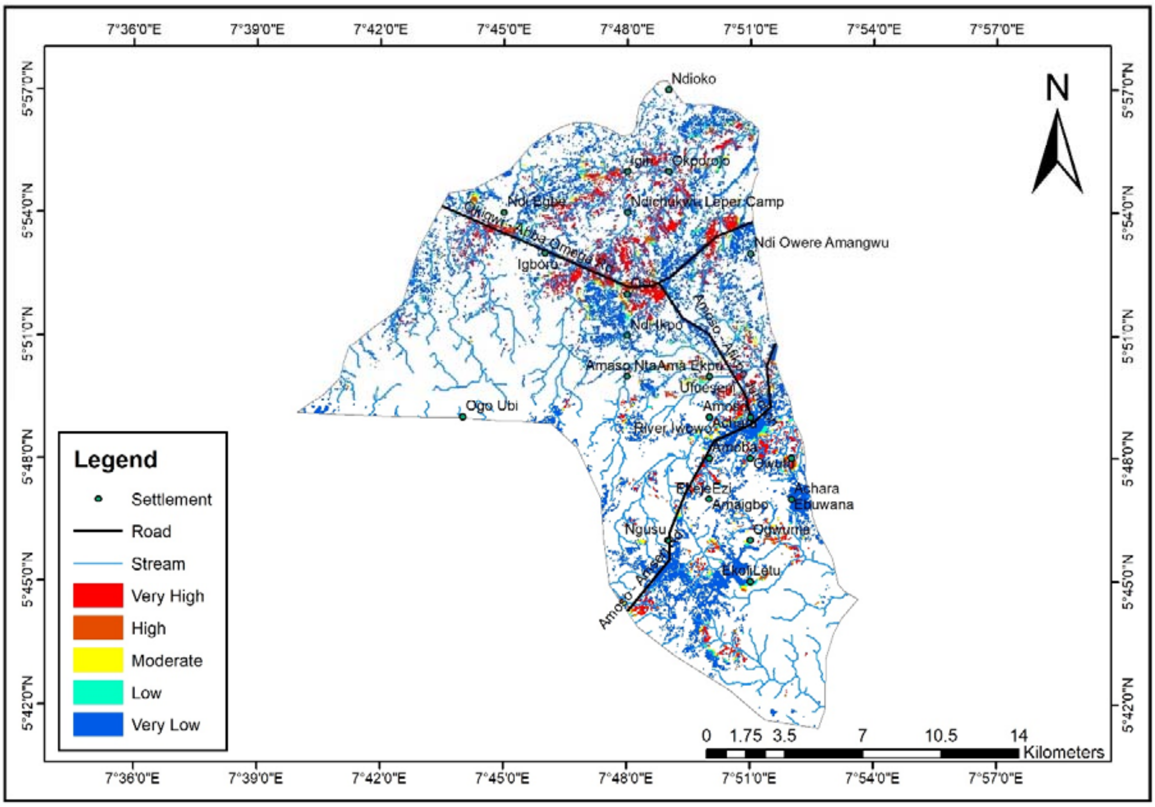

Figure 10: Built Up Vulnerability Map of Afikpo South, Ebonyi State

It can be seen from figure10 that though Afiko is expanding in all side of the area, however more expansion is to the North West in terms of the built up locations.

Conclusion

The study assessed flood vulnerability in Afikpo South LGA in Ebonyi State using remote sensing and Geographic Information System (GIS) data integrated with multicriteria analysis to delineate the flood vulnerable areas based on seven criteria. The study provides information on target areas that may be affected by flood in Afikpo South Local Government. This information is useful for decision making on flood early warning and preparedness as well as in mitigation preparedness within Afikpo LGA.

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