Application of Geospatial Techniques for Analysis of River Inundation and Flood Risk Potential along Lower Niger Basin in Nigeria

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Keywords: Remote sensing;Risk management;Spatial planning

ABSTRACT

The application of geospatial technologies (Remote sensing and GIS) in analysis and management of spatial information is gaining popularity in recent times. It provides information that has proved useful for a wide range of application in disaster management. The evaluation and management of floods constitute the first step and the rational basis of mitigation measures against flood damages. Geospatial techniques have been proved to be the most effective tool for flood analysis. The use of remote sensing and GIS techniques for flood mapping and monitoring is an important tool of information for decision-makers. Therefore, an attempt has been made to apply this modern technique for the assessment of 2012 river inundation and flood risk along lower Niger basin in Nigeria. Time series Moderate resolution imaging spectrordiometre (MODIS) data of NASA terra satellite, SRTM, land use/cover map, population data and geographical information system (GIS) were used for this purpose. The map generated from the non-flood image captured on 20th October 2010 was used as a reference to determine the extent of flooding from the disaster image and the spatial impact was measured based on the proportion of the submerged land territory while physical impact was measured based on the affected population. Six indexes of flood risk identification, namely, elevation, proximity to the river land use, population density Drainage density and flow accumulation were used for flood risk analysis in the study area. Each of these parameters was reclassified into four which included high risk, moderately risk, low risk, and no risk through the ranking process. The objective for using multiple factors was to define areas with the highest risk inducing factors (most likely to flood) and assess how closely these locations are to the actual flooded areas reported during the 2012 flood. Flood risk map (FRM) was later generated by overlaying the reclassified maps of all the parameters using addition operator. The integration of remotely sensed data and other spatial and non-spatial data within the GIS platform was able to produce series of thematic maps which was used to generate a geospatial database for flood risk analysis and assessment. The result of the analysis shows that the areas inundated was also the locations identified as very high risk zones. This effectively demonstrated the contribution of geospatial methods in management of flooding. It was therefore, suggested that policy makers and all stake holders concerned in disaster management should adopt this reliable technique for informed decision making.

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1.0 INTRODUCTION

Flooding is one of the serious natural hazards in the world Emmanuel *et al*, Flooding results when inflow makes a stream channel exceeds its caring capacity. 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.

It is one of the major environmental problems facing man within the century. This is especially the case in most wetlands of the world. The reason of this is the general rise in sea level globally, due to global warming as well as the saturated nature of the wetlands in the Riverine areas. Periodic floods occur in many rivers, forming a surrounding region known as flood plain. Rivers overflow for reasons like excess rainfall. In extreme cases flooding may cause a loss of lives. On 22nd August 2012, torrential rain resulted to the rise of water level in lagdo dam Cameroon. As a result, the Cameroon authority informed the Nigerian government on 23rd of August of the need to open the dam and release excess water. Consequently, the dam was opened on the 24th of August 2012 following the alert given to the Nigeria government a day earlier. The release of the water from the dam coincided with the release of water from the Kainji and Jebba dams located in Niger state into the River Niger. This resulted in flooding of major towns downstream along river Niger-Benue and its tributaries. The unprecedented flood was disastrous than any known event resulting in several damages and untold sufferings to residents along lower Niger basin and entire Nigeria warranting federal disaster declarations. The impact on the communities and local government attracted the attention of state and federal governments who rated many states along lower Niger basin in group A in the flood impact assessment. In order to lessen the negative consequences of flood, risk areas must be identified and protected using appropriate approach.

Fig 1.1 situations during the 2012 flooding in part of the study area

1.2. Aim and Objectives

The aim of this study is to demonstrate the application of Geospatial Techniques for Analysis of River Inundation and Flood Risk Potential along Lower Niger Basin in Nigeria

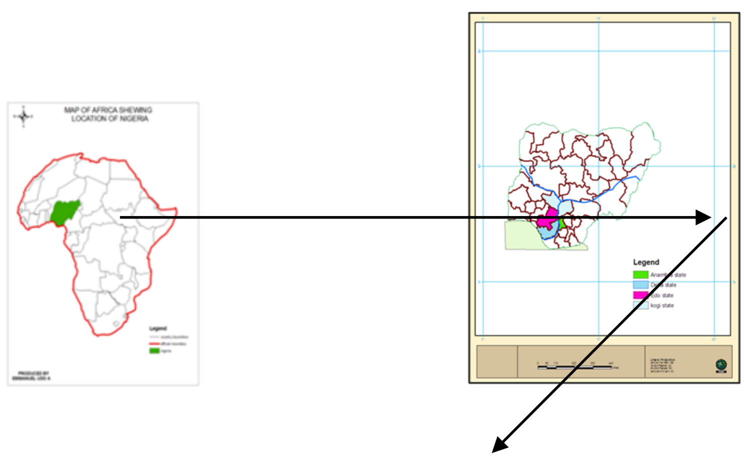
Objectives

- To determine the spatial extent of 2012 flood within the study area
- To understand the general topography, of the study area.
- To determine population vulnerability of the study area.
- Prepare a flood risk map of the study area,.
- To suggest strategies for future flood disaster and risk mitigation in the study area

1.3 Study Area

The area under consideration in this study has a total land mass of 70959 square kilometers which comprises of four states. The states include kogi state (28936 square kilometers), Edo state (19638 square kilometers), Anambra state (4855 square kilometers) and Delta state (17530 square kilometers). Kogi State is located in North central part of Nigeria, Edo state is located in south western part of Nigeria, Anambra State is a state in the south eastern part of Nigeria, while Delta state is located in the south –south in a region known as Niger delta. Geographically the study area is located between latitudes 5°.00`N and 8°.45`N, then longitudes 5°.00`E and 7°.45`E.

Location map



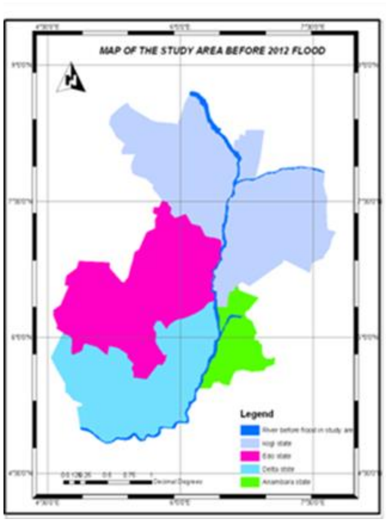


FIG 1.0   LOCATION MAP OF THE STUDY AREA

2.0. MATERIALS AND METHODS

The following materials and data were acquired for this study: Digital Elevation Dataset from Shuttle Radar Topographical Mission (SRTM). This was downloaded from USGS explorer, prior and during 2012 flood remote sensing satellite imageries captured by moderate resolution imaging spectroradiometer (MODIS) on NASAS terra satellite. One was captured on 20th October 2010 before the flood and the other was captured on 13th October 2012 during the peak of the flood, Google earth imagery. The spatial locations of some flooded communities were also acquired with the use of Garmin 72 GPS, Other datasets are administrative map from where political boundaries and roads were digitized. GPS and notebook were also used to acquire and record the coordinates of the communities respectively. Others information are population data from Nigerian population commission, information gathered from NIMET, NEMA, NIWA, publications and through social survey.

2.1 Flood Extent Mapping

The time series imageries and the administrative map were geo-referenced to WGS84 ZONE 32 in Arc-GIS 10.1, using common reference points. The reason for identifying in the same coordinate system is to ensure compatibility between the various environmental data-set. The creation of a personal geodatabase for each feature of interest was done in ArcCatalog extension of the ArcGIS 10.1. The digitizing process was done in the ArcMap environment for feature extraction. Digitizing is the process of converting geographical features from an analogue or raster map into vector format. The true width of the river channel was extracted from pre-disaster imagery as poly- gons (shape file) and in the same process, the flood mask along the river channel from the disaster image was digitized as polygons within the ArcMap platform. The map generated from the non-flood image captured on 20th October 2010 was used as a reference to determine the extent of flooding as shown in **3.1a** and **3.1b** below.

2.2 Overlay Analysis

For detail study, the Niger-Benue River layer and the flood mask layer were both overlaid on the administrative map layer which is disaggregated to the LGA level (**Figure 3.1c**). Spatial erase was carried out on the new map to erase the river feature that falls within the area of the flood polygon this also removed the true width of the Niger-Benue River from the area affected by flood . This procedure was able to separate the flooded area from the actual river channel so as to reveal the spatial extent of the flood; This criteria was adopted from (Felix Ndidi Nkeki 2013) . With the application of GIS spatial analysis, water covered area is synthesized. After the spatial erasing of the true river channel, the flooded area marked by red color was mapped out . The overall affected area along the river basin is 5613sq.km this constitute 8% of the land mass of the study area. The overlay analysis revealed that 26local governments were affected**.** The spatial extents at the affected locations were digitised and calculated using calculate geometry module. The analysis revealed that spatially, Ibaji, was the worst affected local government **Figur3.2a-.**

A ground truthing was also conducted to validate the extent of the flood as captured by the satellite imagery and to identify other flooded areas. During this exercise, the co-ordinate of some flooded locations in the affected communities were captured and added as events to the flood extent map. The validation exercise revealed that flooded water left some footprints on walls of buildings and these footprints were measured with a measuring tape and its mean were calculated to arrive at the average height of flooded water of 6m above the ground level. The mean height of flooded water was considered because the flood height varied from one location to another even in the same communities. Questionnaires were dispatched and interview also conducted.

2.3. Terrain Modelling

Creating the DEM for the analysis requires merging the SRTM DEM tiles into one raster grid entity (mosaicking). Progressively, the tiles were entered into the ArcMap-Arc Info platform for processing. Using the tiles elevation data were mosaicked with data management module of Arc-tool box in ArcGIS 10.1 and the generated data was transformed from geographic coordinate system to projected coordinate system (i.e. from GCS-WGS1984 to WGS1984 World Mercator. The mosaicked data was masked with the boundary limit of the study area and converted to xyz point data. The XYZ point data was exported to surfer10 worksheet where the data was resampled to a grid interval of 40m This criteria was adopted from (Emmanuel Udo 2015). The resampled data was blanked from the blanked file, elevation model contour, wireframe, flow model, slope map and flow accumulation map of the study area were generated. The multiple terrain representation was adopted in other to critically analyze the terrain. These models shows terrain elevation range of between 20m to 600m above mean sea level with elevation decreasing towards the river Niger

2.4 Drainage Delineation

The drainage map is the resultant flow accumulation map developed from the SRTM which sinks has been filled. This was processed using the hydrological module of ArcGIS 10.1. In the hydrological module tool in ArcGIS, before the delineation of drainage can be done, all sinks need to be filled. The sink areas are pixels which have heights that are lower than neighboring pixel values. when it is filled the runoff from the DEM will reach its edges. In the hydrology module the sink in the SRTM was filled using the fill module. The resultant filled raster data was used as input to generate the flow direction raster data using the flow direction module. The output (flow direction raster) was used as input to generate the drainage using the flow accumulation module.

Land Use: The land use of the study area was classified based on visual image interpretation of goggle earth imagery. The land use map reveals that there were about six land use types in the study area and these are built up area, cleared land, farmland, wet lands, forest and water body. The land use was later reclassified into three based on the capacity of each land use type to infiltrate water. It is discovered that built up areas, wetlands and water body will highly support flood generation while farmlands and cleared land are moderately; and forest will be lowly.

2.5 Risk mapping of kogi state:

A risk map demarcates areas under potential consequences. Knowing the areas under potentials danger enables a proper decision to be taken and appropriate measure taken to mitigate the impact before flood strikes. Flood risk map enables facilities at dangerous flood zones to be identified and protected before the event. In this study, the risky areas were zoned using the flow accumulation, proximity to the river, land use, Elevation, Slopes, and drainage density as elements of flood risk identification. Analytical Hierarchical Process (AHP) was adopted in this study whereby these flood factors are ranked and overlaid for decision making. Therefore, each of the parameters was reclassified into four which included high risk, moderate risk, low risk and no risk through the ranking process . Flood risk map (FRM) was later generated by overlaying the reclassified maps of all the parameters using addition operator to generate the risk map of the study area i.e. FRM = Σ {Reclassified (Elevation, Distance to Drainage, drainage Density, land use, Flow direction , and slope)} **(fig3.6b)**. The spatial extents of the risk categories were digitized in layers in form of shape files and the area occupied by each risk category was automatically calculated in GIS environment using calculate geometry module. For in-depth spatial analysis administrative layer of the study area was super-imposed to the risk map. The risk map was validated with the 2012 flood extent map of the study area. This analysis revealed that the areas flooded are, low lying areas and areas closer to the flood plain portrayed as high and moderate risk zones in the risk map

2.5 Exposed population ;

Population exposed to different levels of risk was estimated by integrating the spatial coverage of each risk category with the average population density of study area i.e (Pop. Vulnerability. = Area of risk category * pop. Density)

3.0. RESULTS AND DISCUSSIONS

3.1 Results

Figure 3.1a and b is the comparison before and during flood in the study area **Fig 3.1c** is the overlay analysis of river layer flood layer and the administrative elements of the study area. **fig3.2a** is the area of land in square kilometers inundated at different locations within the study area. **Fig3.2b** is the percentage of land affected in the study area. **Table3.1** reveals the population vulnerable to different levels of flood exposure within the study area. **Fig 3.3a, and b** are **over** lay analysis of the flood layer on the 3-Dmodel of the study area. **Figure3.4a and b are** the, DTM and contour map of the study area. **Figure3.5a and b are** the land use/cover and drainage map of the study area. **Fig 3.6a and b** are Flow accumulation map of the study area and Over lay analysis of the flood layer on the DTM of the study area While (**figures 3.7a and b and c)** are the risk map of the study area , Area of Land occupied by various risk zones and validation of the risk map

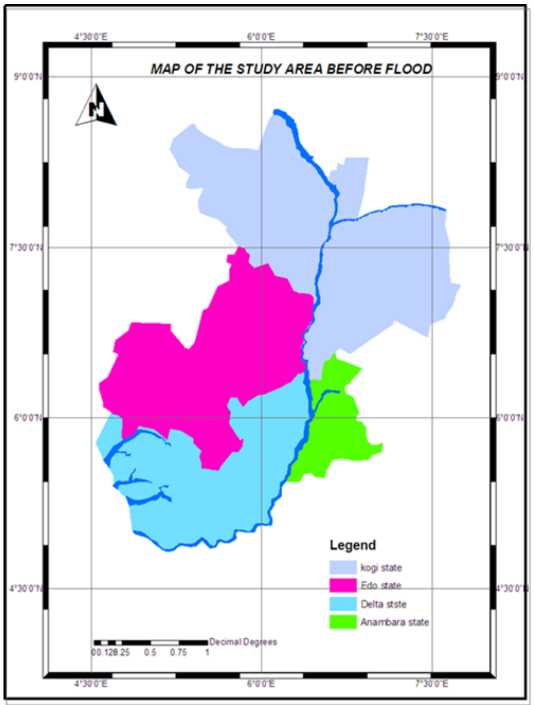


Fig 3.1a

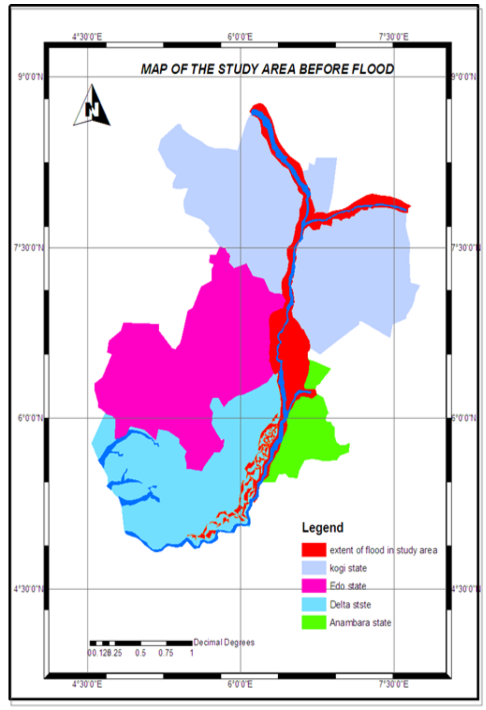


Fig 3.1b

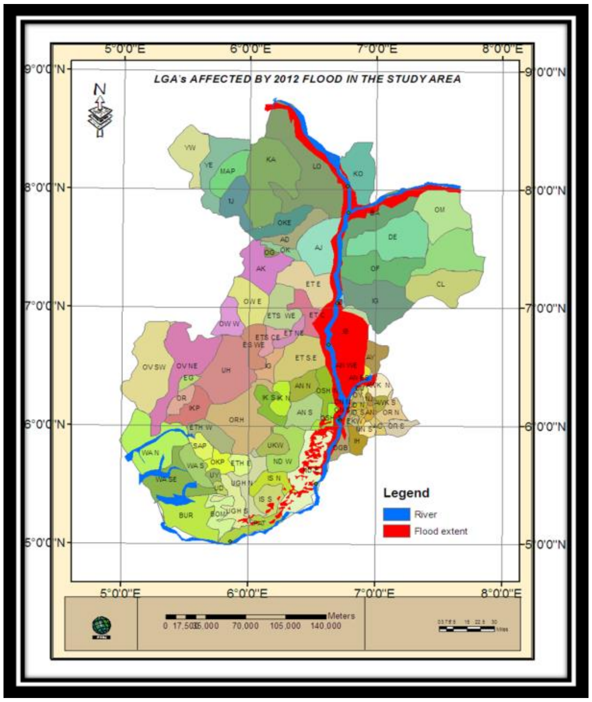


Fig3.1c overlay analisis of river layer, flood mask layer and Adm. Elements of the study area

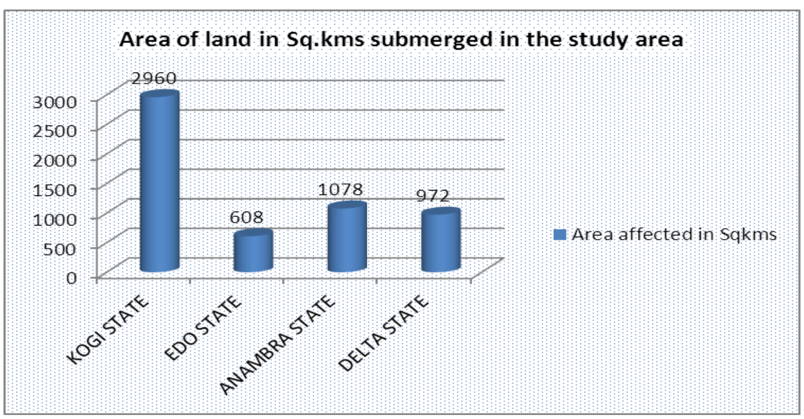


Fig3.2a spatial inpact of the flood on various locationns

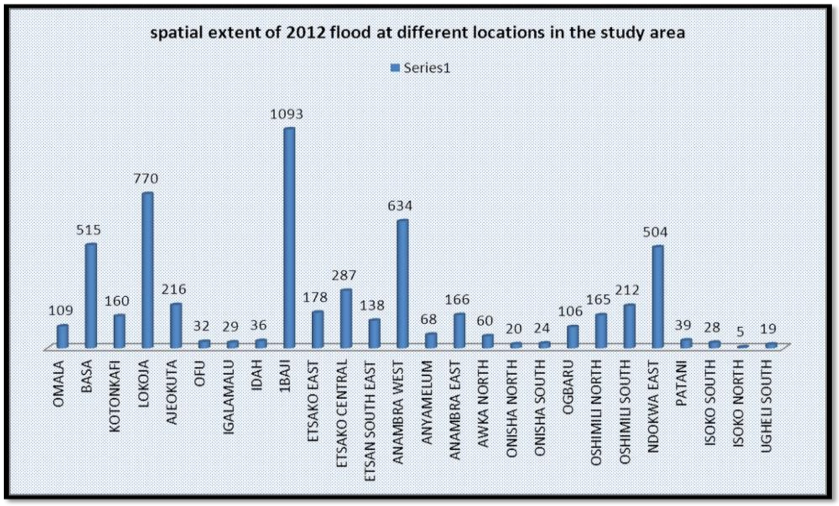


Fig3.2b spatial inpact of the flood on various locationns

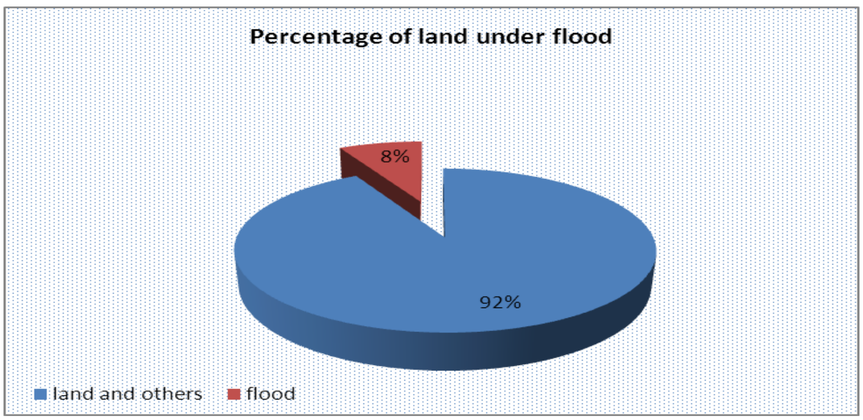


Fig3.2c is the percentage of land affected in the study area

EXPOSURE	POPULATION
HIGH	5925487
MODERAT	4534435
LOW	2292284
NO	2026030

TABLE 3.1 Estimate Of Population Vulnerable To Flood

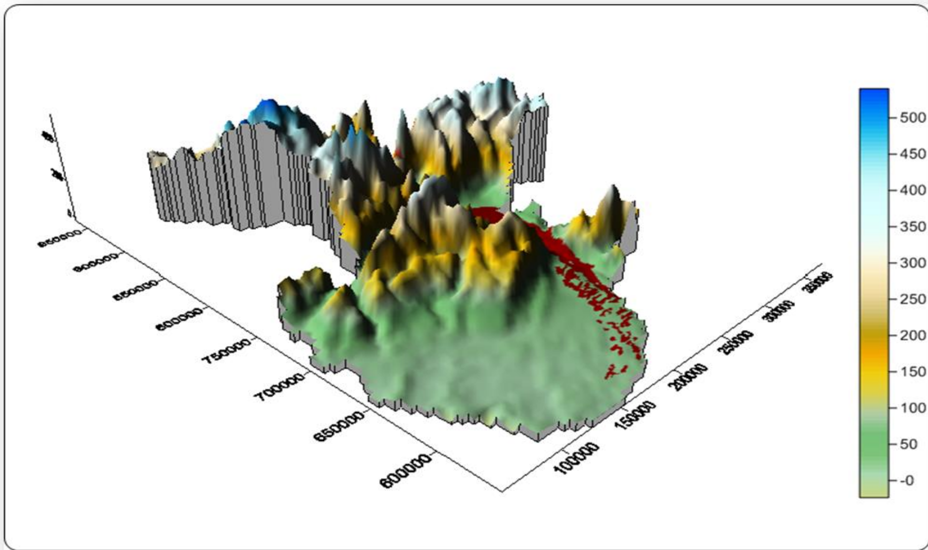


Fig 3.3a over lay analysis of the flood layer on the 3-Dmodel of the study area

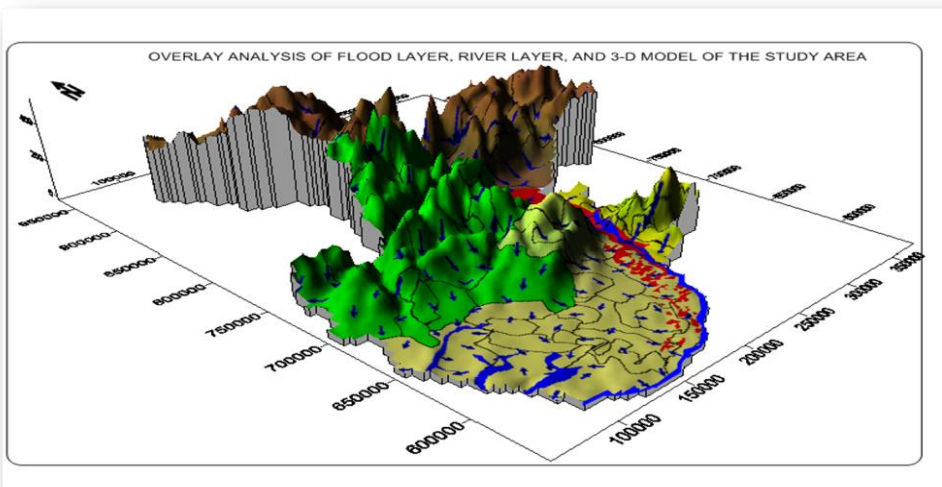
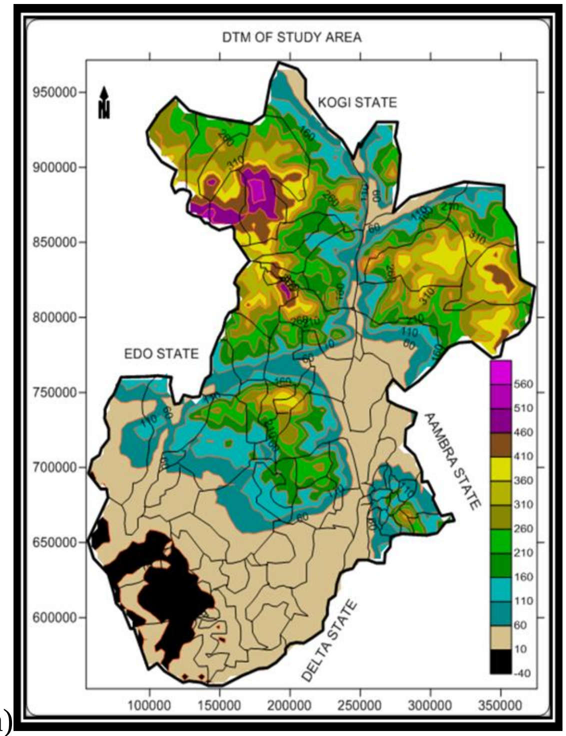


Fig 3.3b Contour over lay analysis of the flood layer on the 3-Dmodel of the study area

(a) 

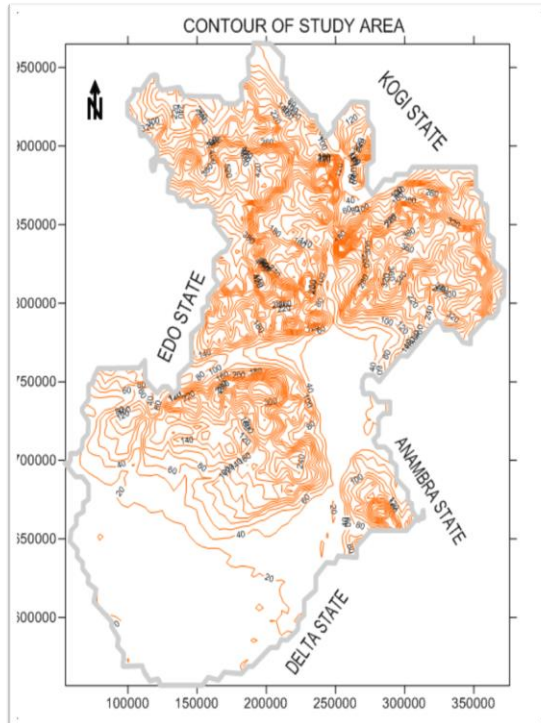
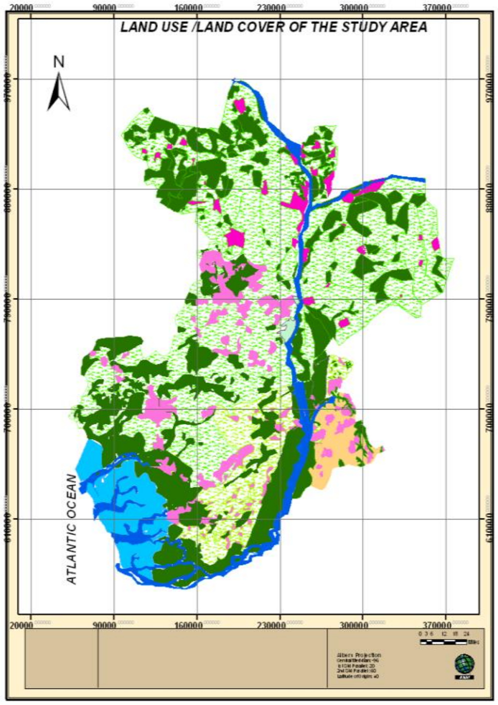
b 

Figure3.4 DTM map of the study area Contour map of the study area



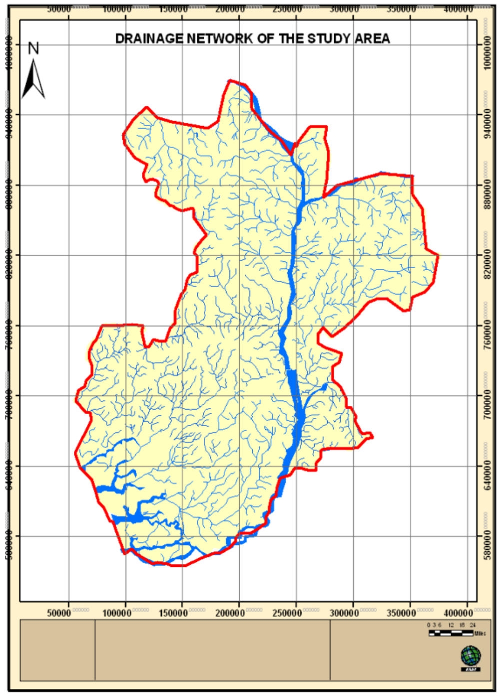
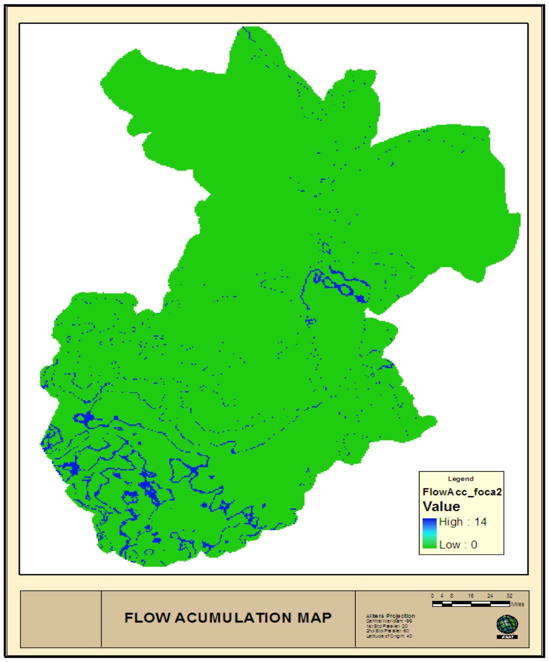
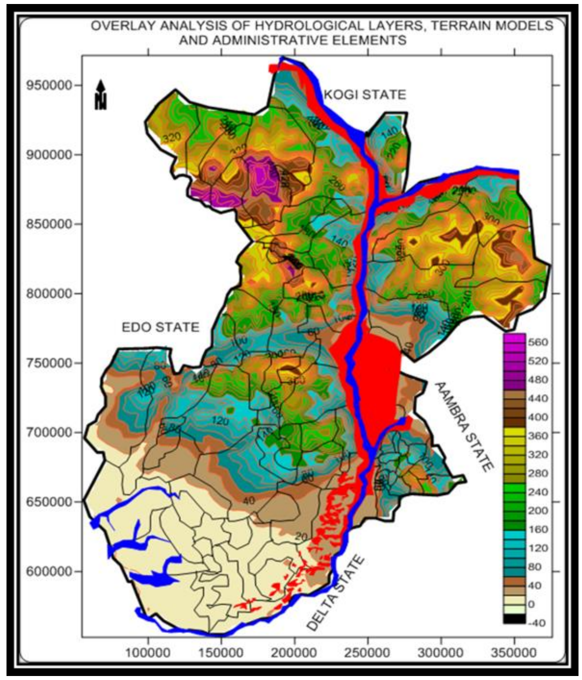
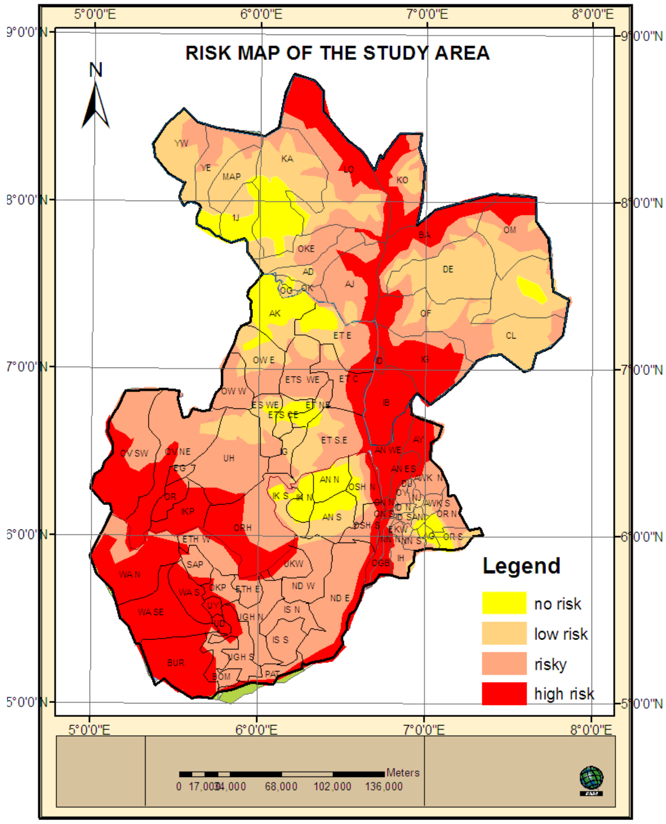


Fig 3.5a Land use map of the study area 3.5b Drainage Map of the study area





a)Flow accumulation map of the study area (b)Over lay analysis of the flood layer on the DTM



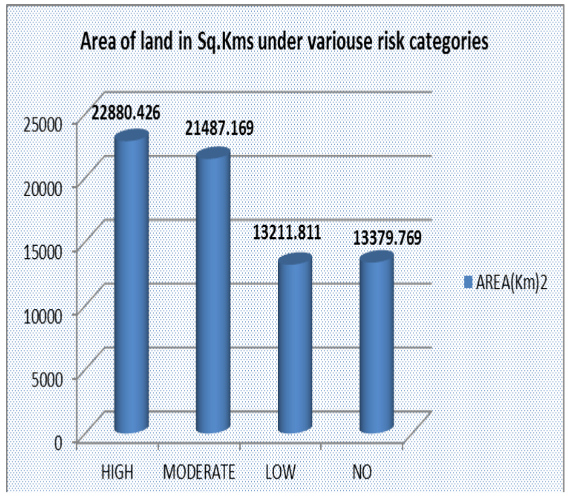
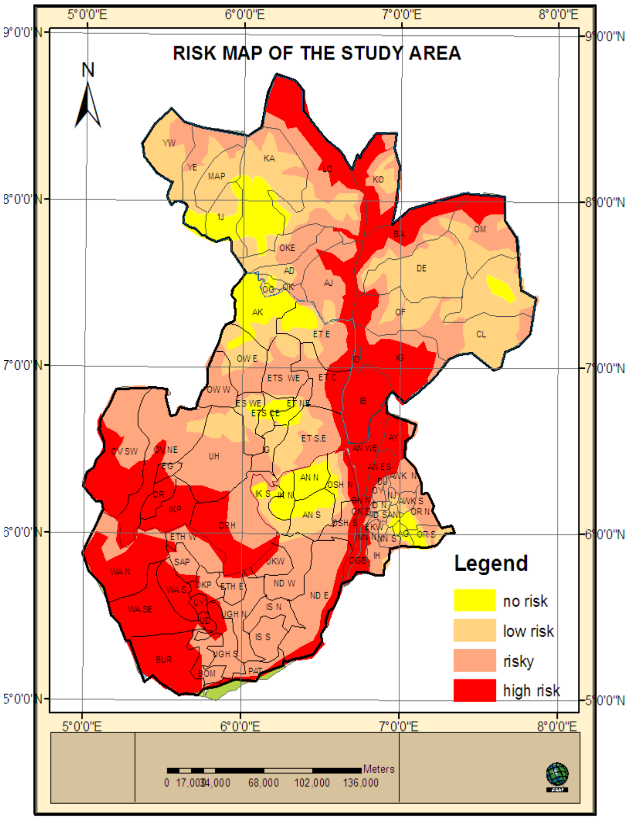
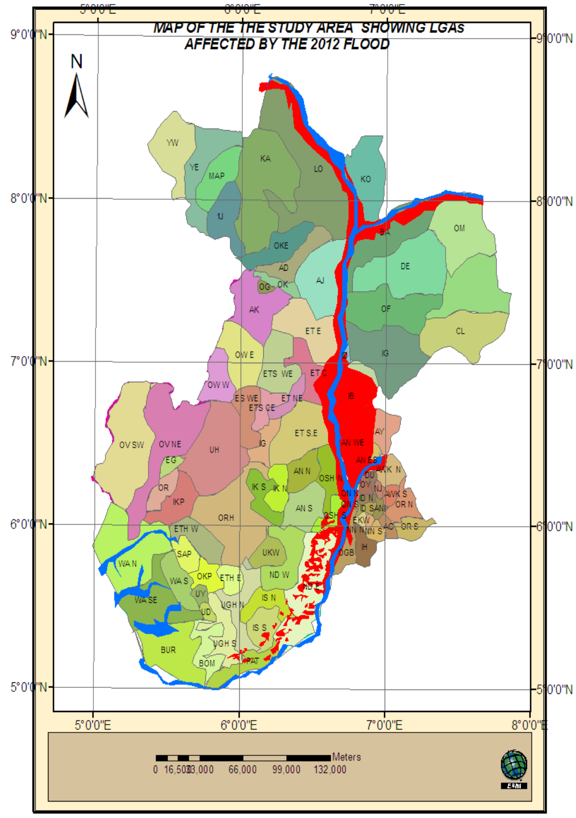


Fig 3.7a risk map of the study area

3.7b Area of Land occupied by various risk zones





3.2 Discussion of Result

In this study, the spatial impact was measured by the portion of the submerged land territory. Overall, this study shows that 5613sq.km of land was submerged and this constitute 8% of the land mass of the study area and the effect of the flood hazard was spread across 26 LGAs of the states (**Figure 3.2b**). The result of the analysis indicates that kogi state is the most affected with 2960 km^2 of its land territory submerged . This is followed by Anambra state with 1078 km^2 of its land sub-merged and next to this is Delta State with 972 km^2 of its land submerged and Edo state with608 km^2 of its land submerged (**fig3.2a**) Quantitatively, the flood risk analysis revealed that the highly risky places covered area of 22880.426 square kilometres while moderately risky covered 21487.169 square kilometers. The lowly risky areas covered 13211.811 square kilometres and no risk covers 13379.789 square kilometres. This analysis further proved that 5925487 4534435, 2292284, and 2026030 persons are residing within the high, moderate, low, and no risky zones.

3.3. Recommendations

In response to the re-occurring flood events in the study area and in Nigeria as a whole,
(1) There is the need to intensify environmental education
(2) Continual risk Mapping of cities in Nigeria.
(3) There is the need for improved land Use Planning in the study area.
(4) policy makers and all stake holders concerned in disaster management should adopt this reliable technique disaster management

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