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River Inundation and Flood Hazard Zonation in Edo State Using Geospatial Technique

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ABSTRACT

In recent times there have been extreme climatic conditions due to climate change. As a result of this, the intensity of rainfall has increased tremendously causing floods in many areas and countries worldwide. It is therefore prudent that such a natural hazard is addressed in a way to reduce the impact it causes onpeople and the environment. In September / October 2012, it displaced millions of people in Nigeria and submerged several square kilometres of landed area in general and farmlands in particular. Although, the National Emergency Management Agency (NEMA) predicted the occurrence of the flood disaster and advised the relocation of residence from the flood-plain to the high ground, but spatial information pertaining to the areal extent at risk was not made available. This study attempted to assess the spatial impact of the 2012 flooding in Edo state using the moderate resolution imaging Spectroradiometre (MODIS) data of NASA Terra satellite and developed a geospatial methodology for detecting and extracting the flood hazard areas and estimate population exposed to flooding within the study area. Time series Moderate resolution imaging spectroradiometre (MODIS) data of NASA terra satellite, SRTM, land use/cover map, population data and geographical information system (GIS) were used for this purpose. Five indexes of flood hazard identification, namely, elevation, proximity to the river land use, population density, slope and flow accumulation were used for flood hazardanalysisin the study area. Each of these parameters was reclassified into five which included very high hazard, high hazard, moderately hazard, lowhazard, and no hazard through the ranking process. The objective 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 hazard map (FRM) was later generated by overlaying the reclassified maps of all the parameters using addition operator. This study revealed that the areas flooded in the 2012 disaster measures 608sq.kms and is included within the areas identified as very high hazard zones. Quantitatively, the flood hazard map shows that the very high hazard areas covers4828.808 square kilometers (24.59%) highly hazard places covered area of 5908.936 (30.09%)square kilometerswhile moderately hazard covered 2942.184 square kilometers (14.98%), The lowly hazard areas covered 4353.552 square kilometers (22.17%) and no hazard covers 1604.52square kilometers (8.17%). This analysis further estimates that791355, 968368, 482171, 713469, 262952 number of persons resides within the very high, high, moderate high, low and no hazard zones. These correspond to approximately 25%, 30%, 15%, 22% and 8% of the total population of the state

Keywords: *Risk, Flood Disasters, GIS, Vulnerability, MODIS*

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I. INTRODUCTION

Flooding is one of the serious natural hazards in the world (Emmanuel et al, 2015).It has become a common natural disaster which has claimed many lives, displaced millions and resulted to the destruction of properties and degradation of con-tiguous farmlands. (Felix Ndidi 2013) 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. The immediate effects of flood are displacement of people and damage of properties apart from the threat to disease, also farm land and agricultural products will be destroyed which often leads or result to poverty, hunger and starvation in addition to the cost of reconstruction and reclaiming the affected areas. Flooding is defined as a large amount of water covering an area that was usuallydry (Olajuyigbe et al., 2012). Nwafor (2006) defined flood as a natural hazard like drought and desertification which occurs as an extreme hydrological (runoff) event

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 hits Edo state in the month of September 2012 destroying economic activities in the agrarian communities. NEMA noted that the raging flood affected 100,000 persons in Edo State. In some areas only farm lands were affected while in others both homes and farm lands were all swept away. The unprecedented flood was disastrous than any known event resulting in several damages and untold sufferings to inhabitants of Edo state 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 the state in group B in the flood impact assessment. In order to lessen the negative consequences of flood, hazardous areas must be identified and protected using appropriate measures.

Fig 1.1situations during the 2012 flooding in Edo state

1.2. Aim and Objectives

The aim of this study is Flood hazardmodelling and spatial impact assessment of 2012 flood in Edo state Nigeria using geospatial technique

Objectives

- To determine the spatial Impact of 2012 flood inEdostate.
- To understand the general topography, of the study area.
- To estimate the population exposed to flood in the study area.
- To Prepare a flood hazard map of the study area,.
- To proffer appropriate technological flood hazard reduction approaches

1.3 Study Area

Edo state which was created in 1991 out of the old Bendel state is one of the Niger Delta States. Edo has a population of 3218332 comprising of 1640461 males and 1577871 females based on 2006 census. The state covers a land mass of about 19638SqKm. The land mass has a relatively flat tertian in the southern part with dissecting Platue and hill in the Northern part of the state. The state can be broadly divided into two parts i.e. the basement complex rocks of the north with little or no prospect of exploitable ground water and the sedimentary rocks of the south with relatively high ground water potential. The hydrology is a reflection of the geology and is dominated by the extensive river Niger floodplain in the east and other rivers such as the Ubo, Edion, Orle, Okhuemahun and Owena. These are the numerous sources of irrigation in the state. Slopes of varying gradient exist and contribute to the problem of flood and erosion in the state. The state lies within the rain forest belt in the southern and central district and Guinea savannah vegetation in the North. There is relatively high rainfall, the average annual rainfall ranges from 1400mm in the northern extremity to 2000mm in the south. There are two seasons, the dry and the wet season. The wet season last from April to October while the dry season last from mid-October to March.

Location Map

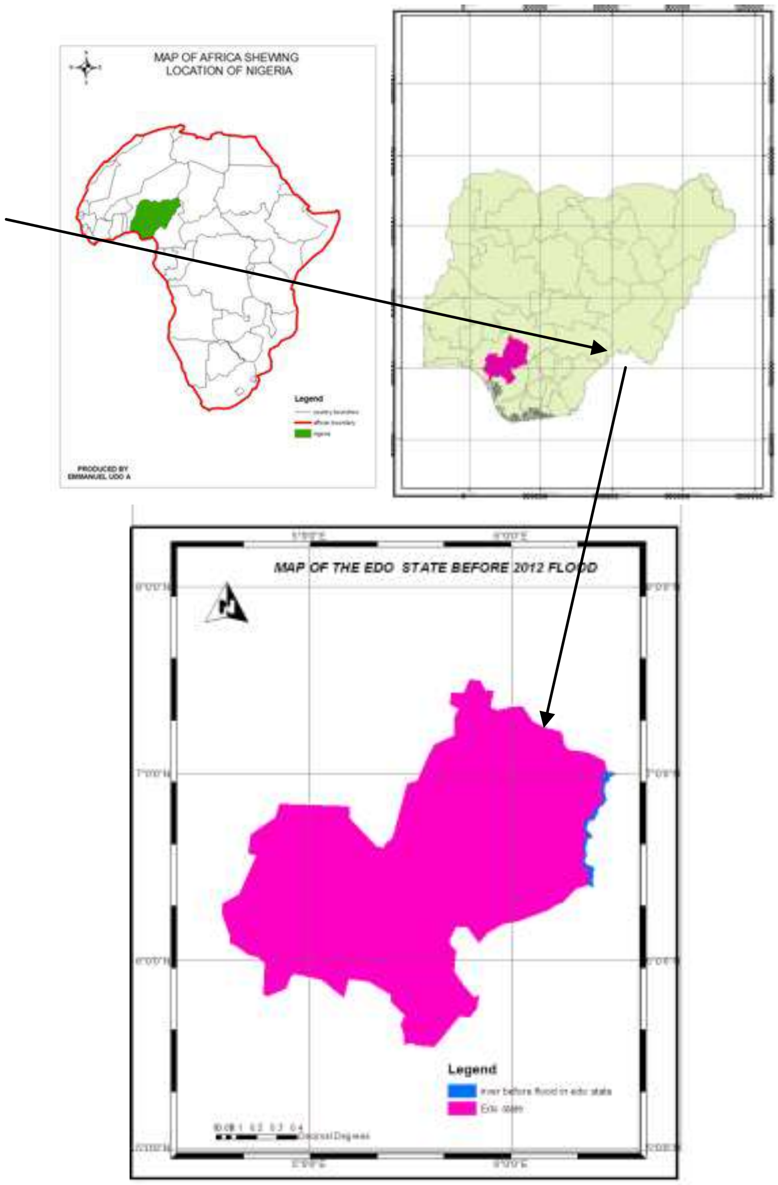


Fig 1.2 Location map

II. 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. 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 9.3, 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 9.3. 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 imageryas poly- gons (shape file) and in the same process, the flood mask along the river channel from thedisaster imagewas digitized as polygons within the ArcMap/ArcInfo 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 NdidiNkeki 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 is mapped out . The overall affected area along the river basin is 608 km^2.. The overlay analysis revealed that three local governments were affected among which are**Etsako East, Etsako central and Etsan south east local governments.** The spatial extents at the affected locations were digitised and calculated using calculate geometry module. The analysis revealed that spatially, Etsako central 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 4m 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 9.3 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 20m This criteria was adopted from (Emmanuel Udo 2015). The resampled data was blanked from the blanked file, elevation model (figure 3.4a), 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 500m above mean sea level with elevation decreasing towards the river Niger and south western part of the study area

2.4 Hazard mapping of Edo state:

Hazard 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 hazard map enables facilities at dangerous flood zones to be identified and protected before the event. In this study, the hazard zonation was conducted using flow accumulation, proximity to the river, land use, Elevation, Slopes, population density and historical flood extent 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 five which included very high hazard, high hazard, moderate hazard, low hazard and no hazard through the ranking process . Flood hazard map (FRM) was later generated by overlaying the reclassified maps of all the parameters using addition operator to generate the hazard map of Edo state i.e. FHM = Σ {Reclassified (Elevation, Distance to Drainage, population Density, historical flood extent, Flow direction , and slope)} (**fig3.6b)**. The spatial extents of the hazard 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 Edo state was super-imposed to the hazard map. The hazard map was validated with the 2012 flood extent map of Edo state. This analysis revealed that the areas flooded are, low lying areas and areas closer to the flood plain portrayed as veryhigh hazard zones in the hazard map.

2.5Exposed population;

Population exposed to different levels of risk was estimated by integrating the spatial coverage of each hazardcategory with the average population density of the state i.e (Pop. Vulnerability. = Area of risk category * pop. Density) see table 3.1

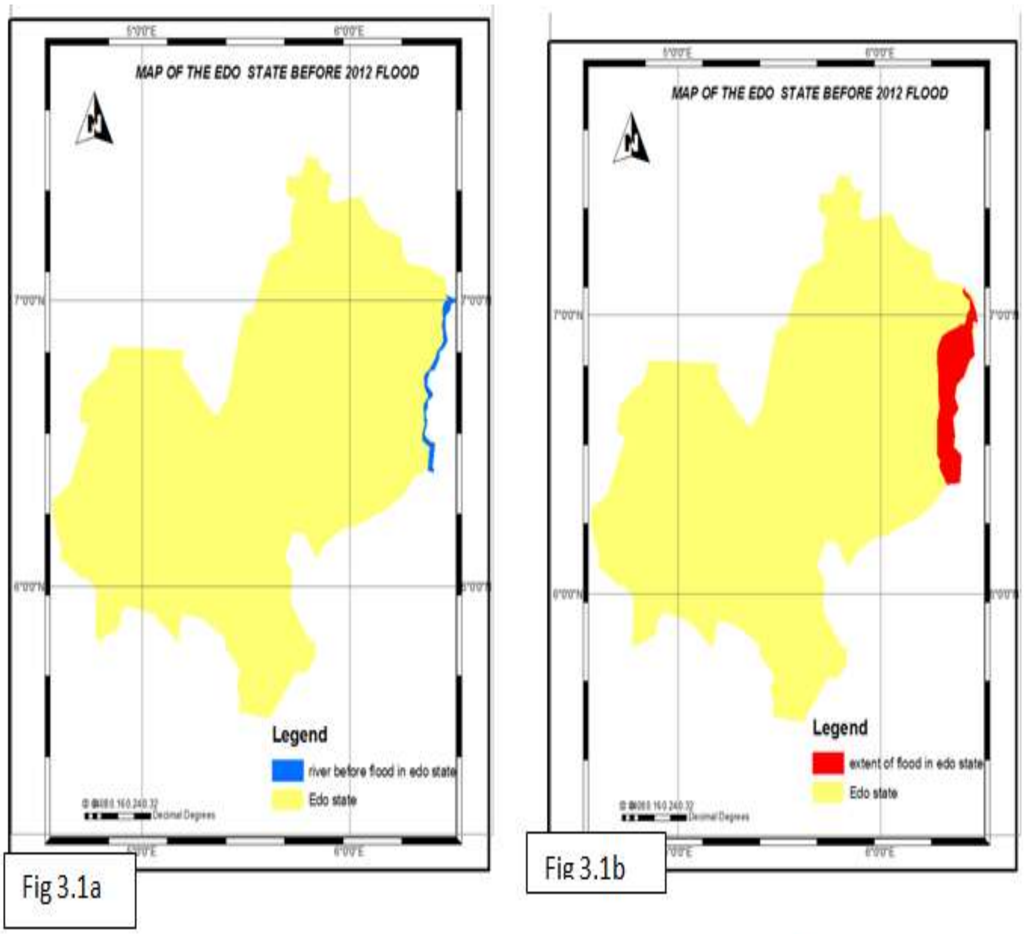
TABLE 3.1 PopulationVulnerability Of Edo State

Vulnerability	Population	Percentage
Very High	791355	25
High	968368	30
Moderate	482171	15
Low	713469	22
No	262952	8

III. RESULTS AND DISCUSSIONS

3.1 Results

Figure 3.1a and bis the comparison before and during flood in the study area **Fig 3.1c** is the overlay analysis of river layer floodlayer and the administrative elements of Edo state. **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. **Fig 3.3a, and b** are the contour map and wire frame of Edo state. **Figure3.4a**is the overlay analysis of the, DTM and contour map of the study area.**Figure3.4b**is the 3-D model of the study area**Figure3.5a**is the reclassified elevation map of the study area.. **Fig 3.6a and b** are hazard map based on proximity to the river and the hazard map generated by integrating the flood inducing factors, While (**figures 3.7a and b and c)** are the charts revealing the area of land occupied by the hazard zones, percentages of land occupied by the hazard zones and the population exposed to different categories of risk



Situations before and during the 2012 flood in the study area

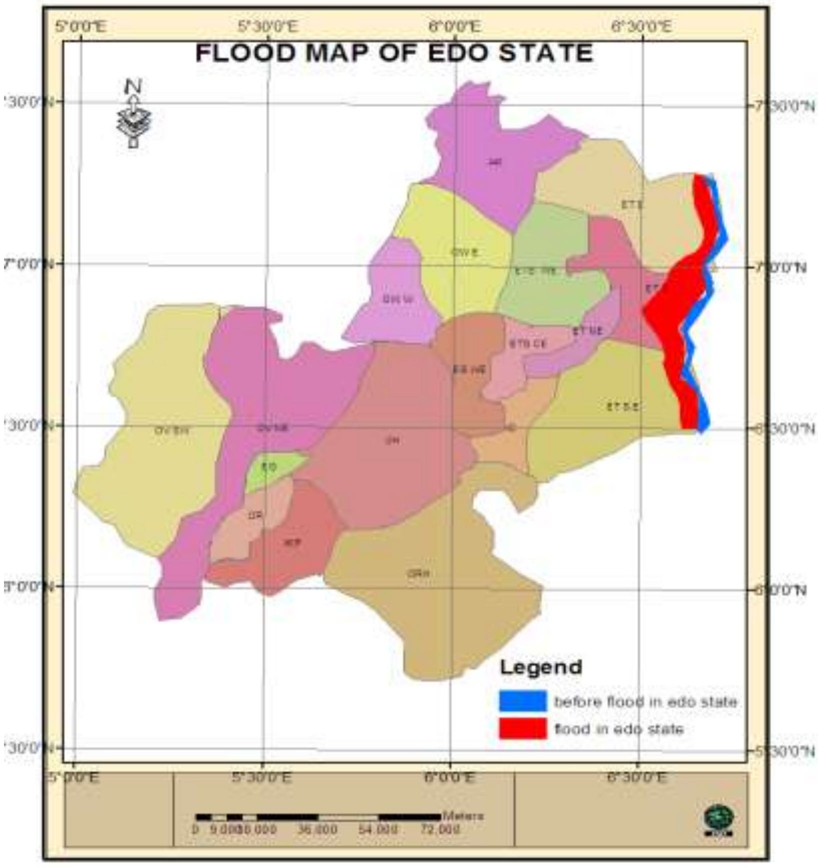


Fig3.1c overlay analisis of river layer, flood mask layer and Adm. Elements of the study area

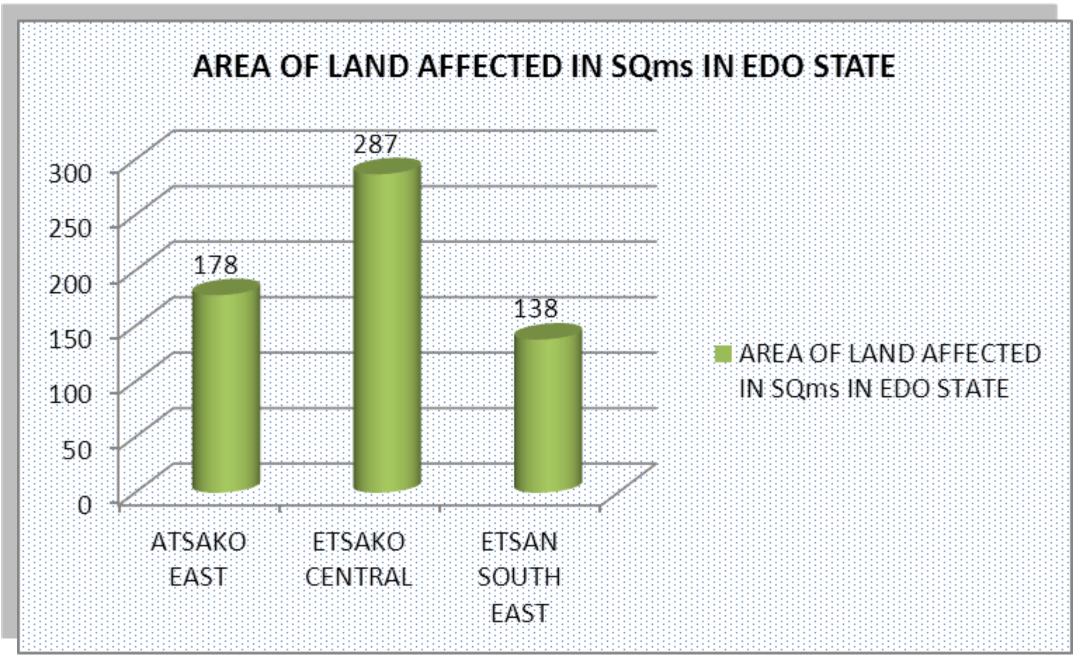


Fig3.2a spatial inpact of the flood on various locations.

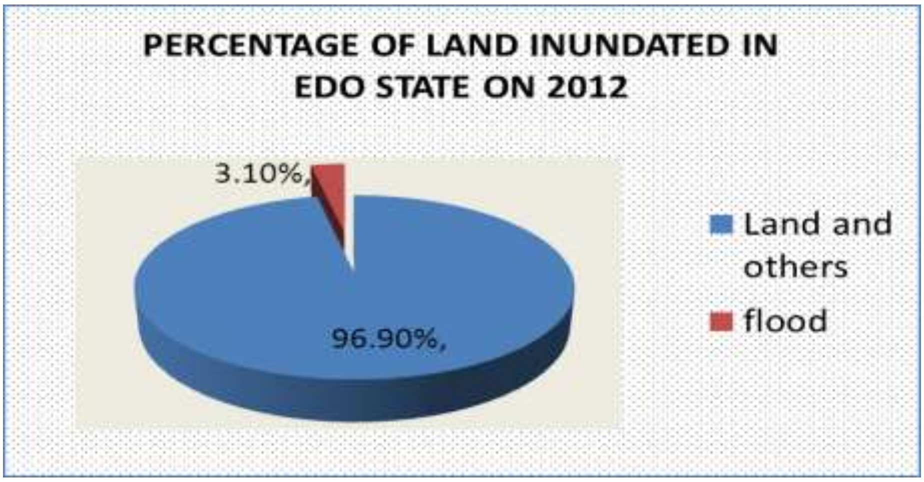


Fig 3.2b

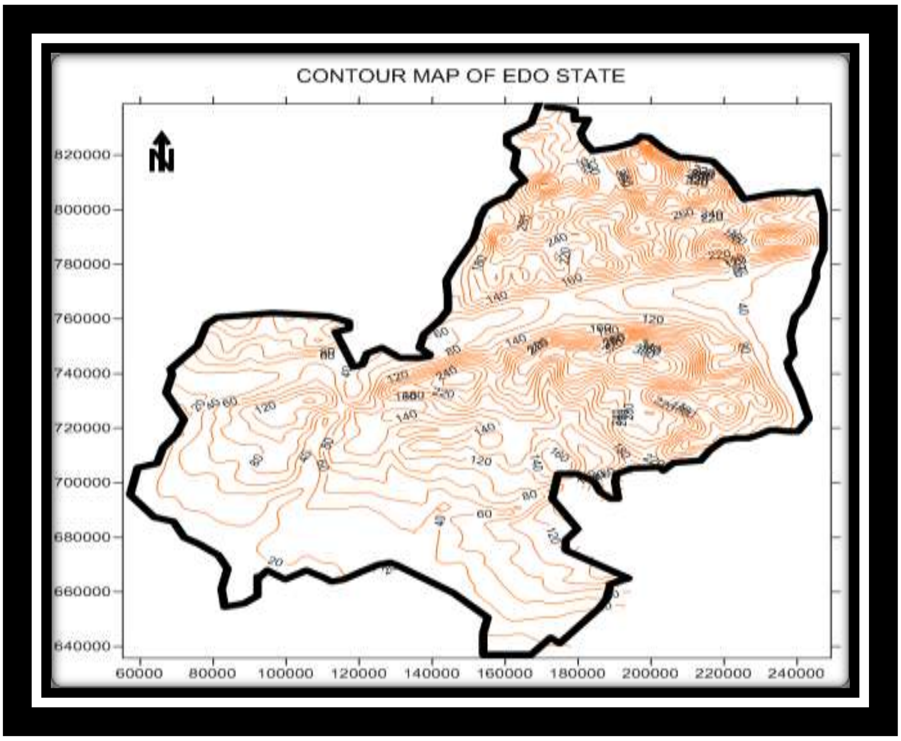


Fig 3.3a Contour Map Of The Study Area

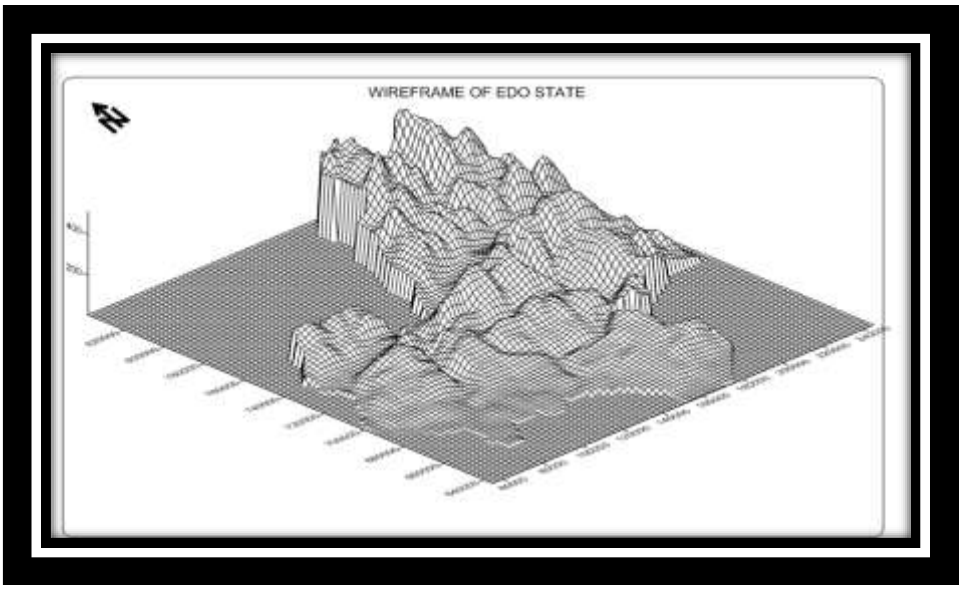


Fig 3.3b wireframe Of The Study Area

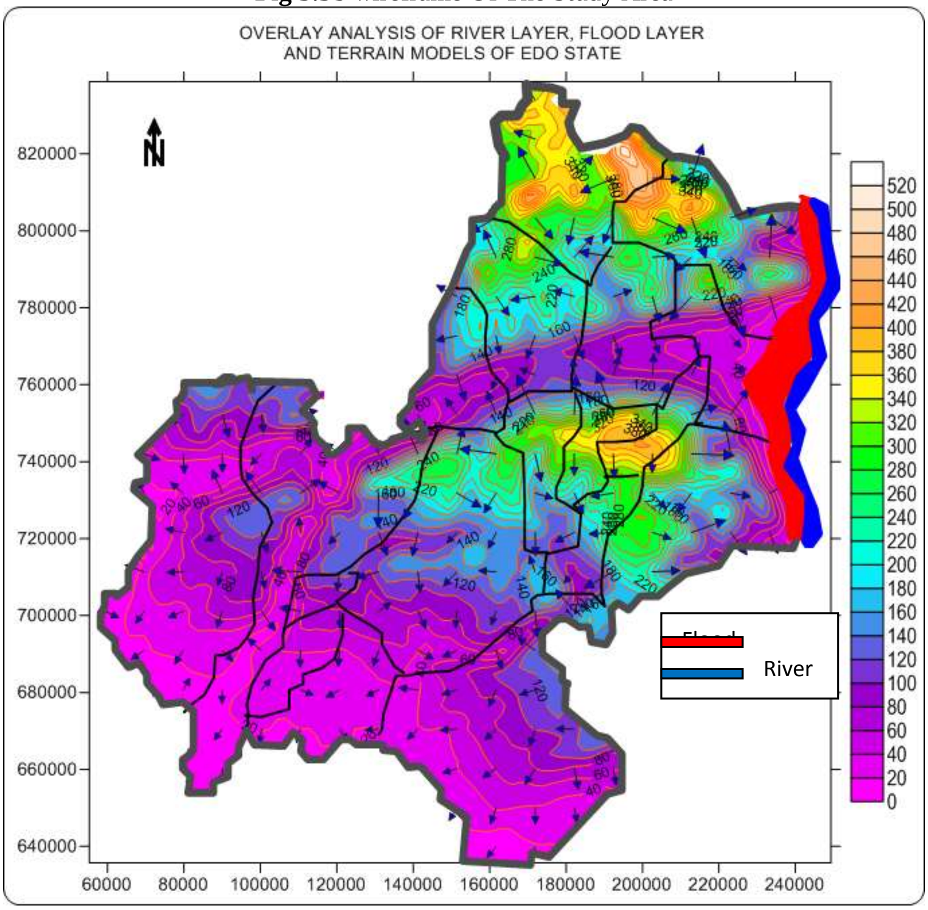


fig3.4a Overlay Analysis Of The Terrain Models And The Administrative Elements In 2-D

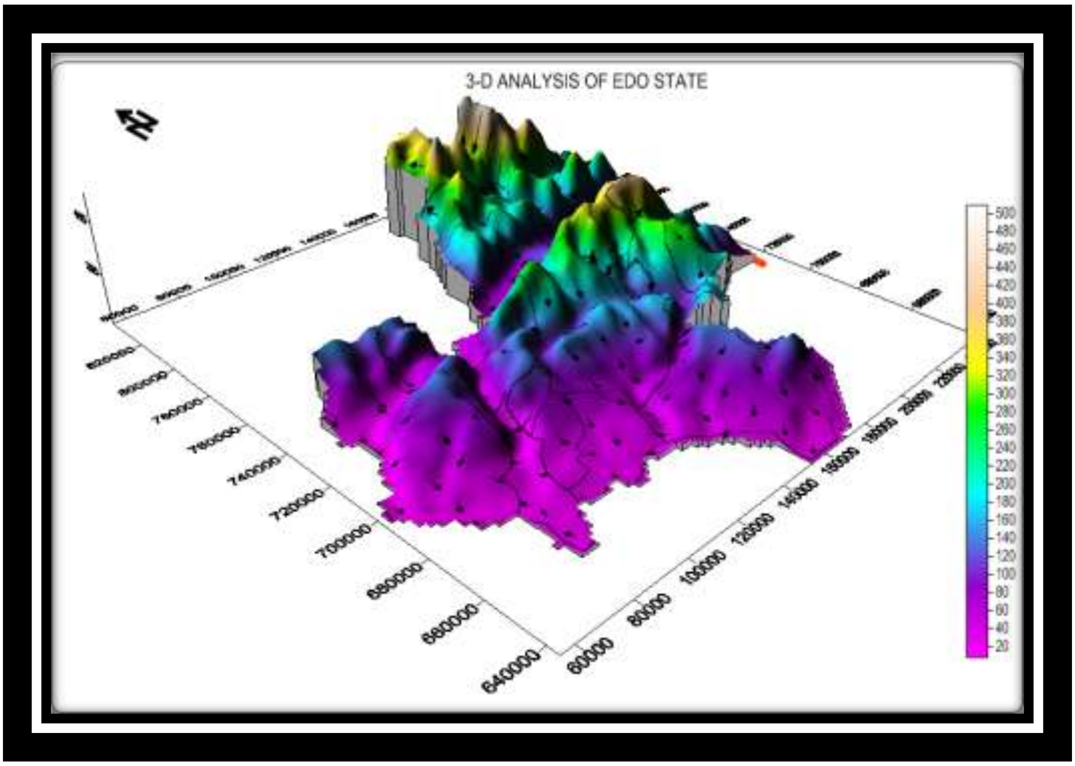


fig3.4b Overlay Analysis Of The Terrain Models in 3-D

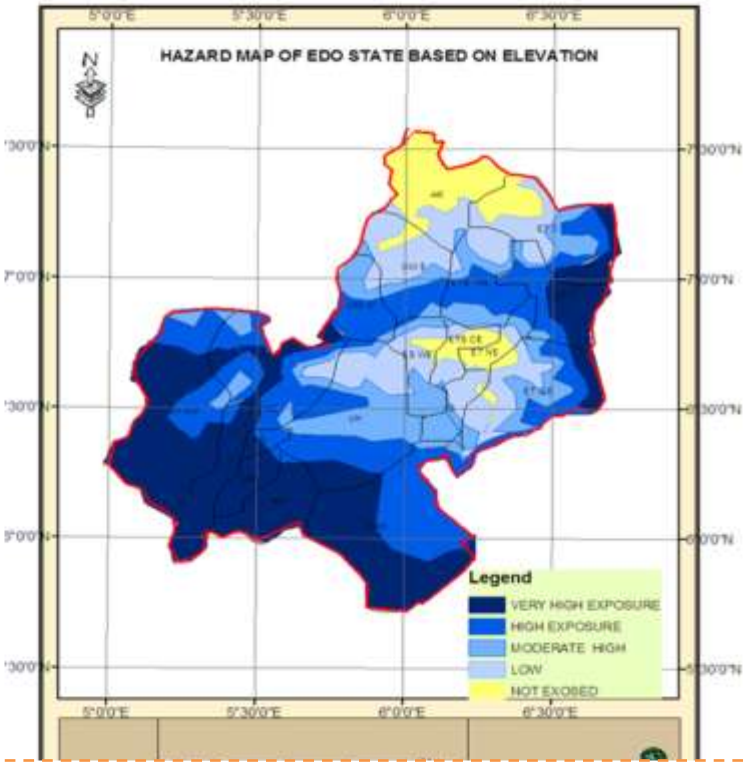


Fig 3.5Reclassified map based on elevation

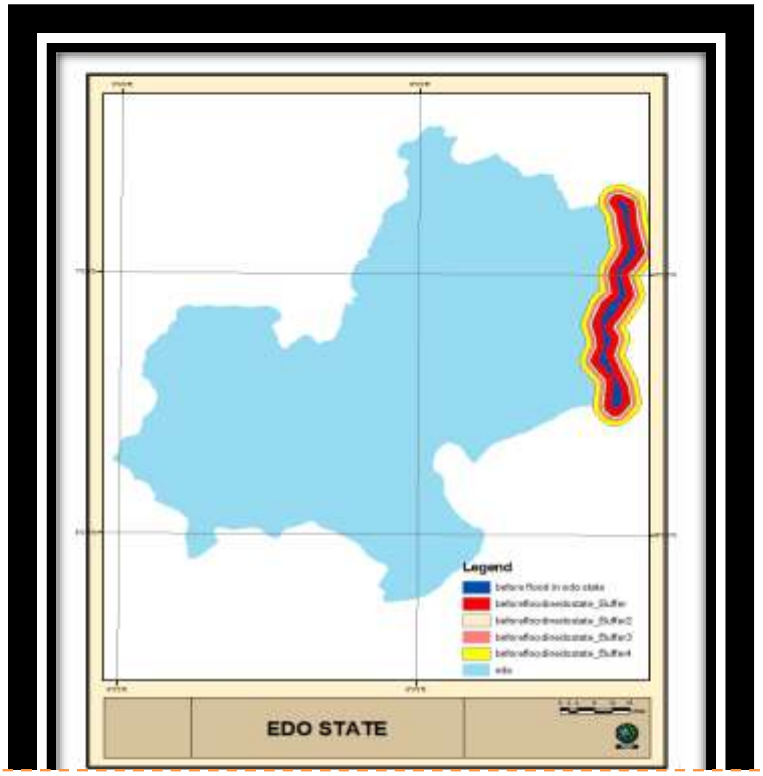


Fig 3.6a reclassified map based on proximity to the river

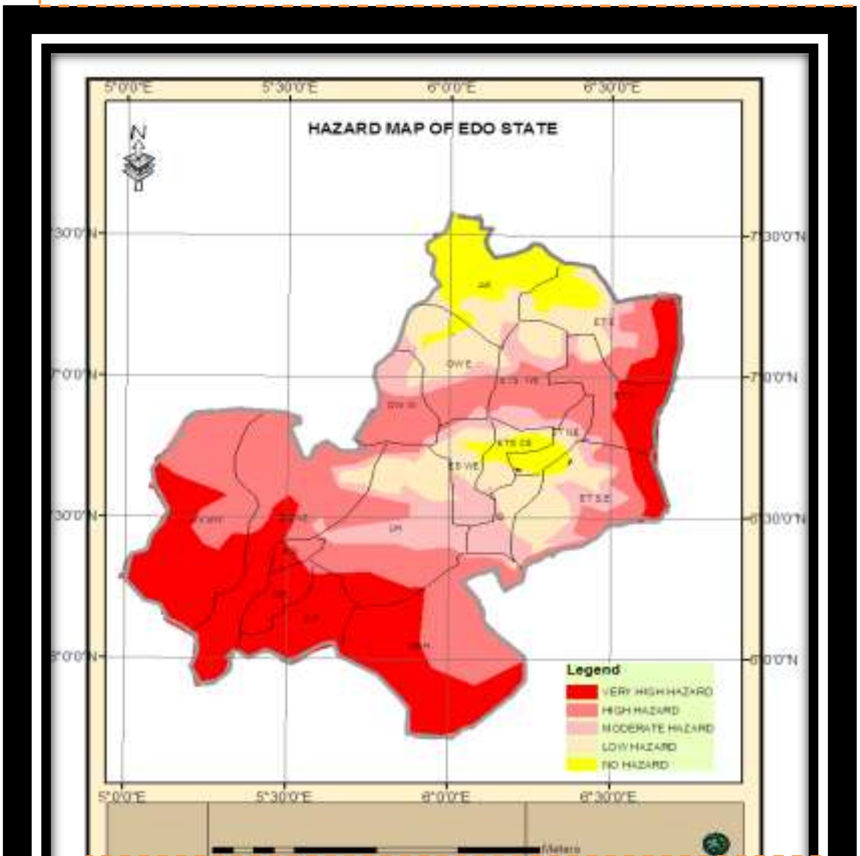


Fig 3.6b Hazard map of the study area

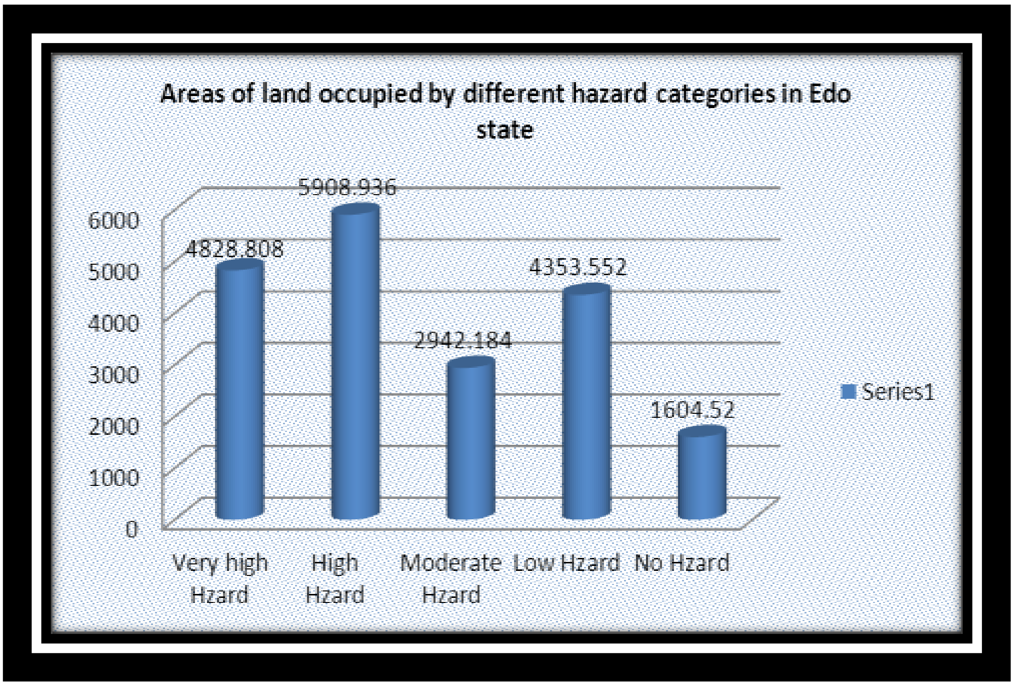


Fig3.7a Area Of Land Occupied By The hazard Zones

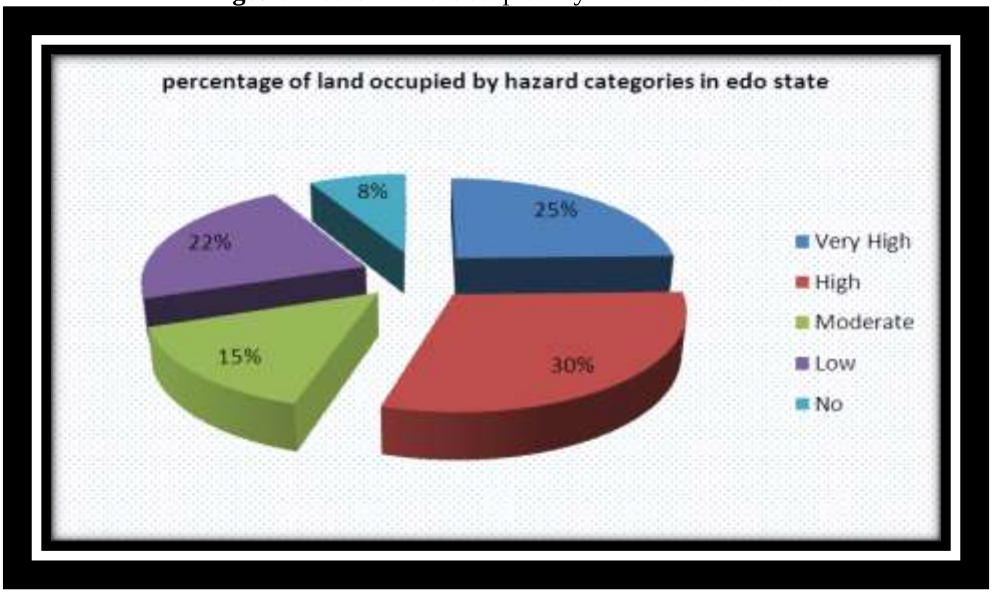


Fig 3.7b percentages of land affected by hazard categories

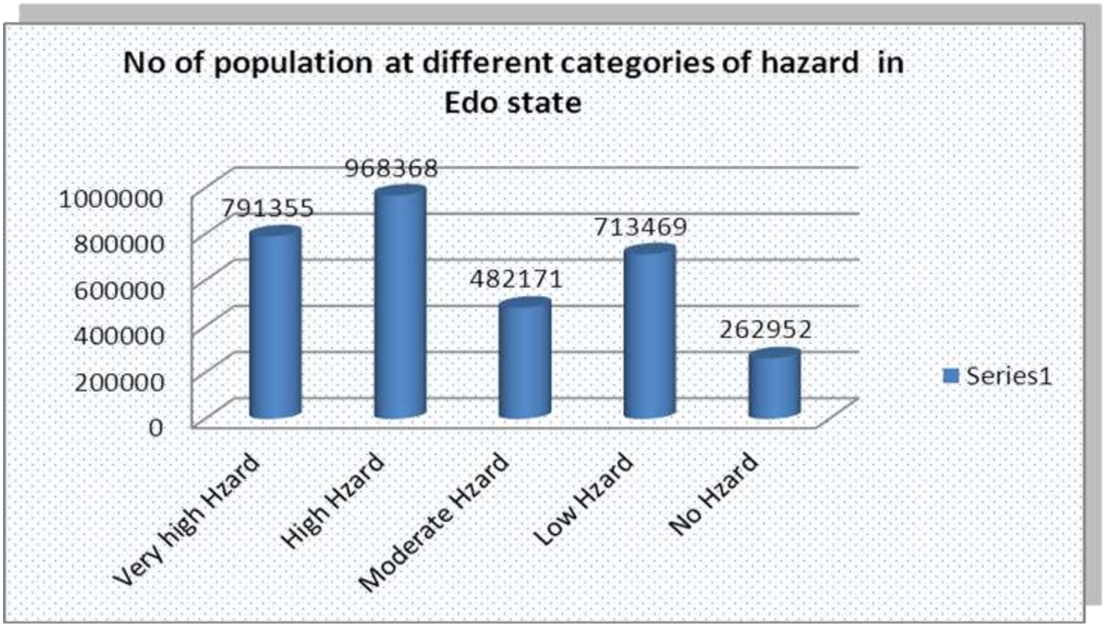


Fig 3.7c population exposed to different levels of flood risk categories

3.2 Discussion of Result

In this study, the spatial impact is measured by the portion of the submerged land territory. Overall, this study shows that 608 square kilometers of land was sub-merged by the flood disaster (excluding the true water path) and this constitute 3.10% of land mass of the state and the effect of the flood hazard is spread across 3 LGAs of the states (**Figure 3.2a**). The result of the analysis indicates that Etsako central LGA is the most affected with 287km^2 of its land territory submerged. This is followed by Etsako East with 178 km2 of its land sub-merged and next to this is Etsan south east LGA with and 137 square kilometers of its land submerged . Quantitatively, the flood hazard map shows that the very high hazard areas covers 4828.808 square kilometers (24.59%) highly hazard places covered area of 5908.936 (30.09%) square kilometers while moderately hazard covered 2942.184 square kilometers (14.98%), The lowly hazard areas covered 4353.552 square kilometers (22.17%) and no hazard covers 1604.52square kilometers (8.17%). This analysis further estimates that 791355, 968368, 482171, 713469, 262952 number of persons resides within the very high, high, moderate high, low and no hazard zones. These correspond to approximately 25%, 30%, 15%, 22% and 8% of the total population of the state**3.3.**

IV. RECOMMENDATIONS

In response to the re-occurring flood events in Edo 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) flood monitoring and management should be encouraged and funded by government and non- governmental agencies.

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