Flood Risk Assessment in Uyo Urban, Nigeria Using Geospatial Tools

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Abstract: *Due to the uncountable and catastrophic effects of natural disaster like flooding in different places all over the world, Application of GIS and remote sensing technology to map flood areas will make it easy to plan measures which reduce the flood damages and risks involved. It will be a great benefit to the people to implement a flood management program that consists of flood forecasting, flood hazard and vulnerability mapping. This study used GIS and remote sensing to identify flood risk areas within Uyo Urban so as to produce an easily understood GIS based flood risks map of the area. The ASTER DEM and Landsat ETM+ images of 2015 of the area were used in this research to characterise the topography and assess the impact of flooding. Three flood risk maps were produced identifying three category risk zones, high, medium and low risk zones. Factors that affect flooding in the study area were outlined and they include population explosion, urbanization and blockage runoff. Some recommendations were made to help researchers to improve on flood management in the country which include, Provision of adequate drainage and channelization system as well as adhesiveness to the regulated planning scheme in Uyo Urban should be monitor by researchers and furthermore, the need to monitor the various urban expansion and flood incidences within Uyo Urban, that more research should be made in this area using this study as the base line data.*

Keywords: Flood, Natural Disaster, Remote Sensing, GIS, Uyo Urban, Flood Risk Zones, Management.

1. INTRODUCTION

Flooding is a general temporary condition of partial or complete inundation of normally dry areas from overflow of inland or tidal waters or from unusual and rapid accumulation or runoff[8]. According to [3], a flood can be defined as a natural phenomenon that results in the temporary submerging with water of a land that does not occur under normal conditions. As they are naturally occurring, they cannot be prevented and have the potential to lead to fatal causes such as displacement of people and damage to the environment [1]. Floods can be caused by anthropogenic activities and human interventions in the natural processes such as increase in settlement areas, population growth and economic assets over low lying plains prone to flooding leading to alterations in the natural drainage and river basin patterns, deforestation and climate change [3]. Flooding incidents have claimed many lives, rendered many others homeless and disrupted a wide range of environmental factors and socio-economic activities related to agriculture, vegetation and sustenance of human and wild life [3]. [1] reported that floods have caused over 10,000 deaths in the United States since 1900.

The study area is Uyo Urban, the capital city of Akwa Ibom State, Nigeria. The city lies between longitudes $37^0 50'$ E and $37^0 51'$ E, and latitudes $55^0 40'$ N and $54^0 59'$ N. Uyo the Capital City covers an approximate area of 188.024 km^2 with an estimated population of 305,961. It was a district headquarters during the colonial era and was later upgraded to a local government headquarters. In 1987, it was further upgraded to the status of a State Capital, with the changes in the status of the area, developments were attracted.

1.1 History of Flooding in Nigeria

Floods are an extreme naturally occurring weather event that results in an overflowing of large amounts of surface water over land that is not always inundated [1]. It is considered to be the worst natural disaster in the world and it is responsible for a third of all-natural problems and half of damages on facilities around the globe. It has become one of the most frequent natural occurrences in the last few decades [8].

Floods have cost damages to societies totaling more than 250 billion dollars and the intensity and frequency of floods are increasing globally [8]. It is gradually becoming a common phenomenon around the world, caused by increase in global temperatures that result in torrential rains and rise in sea level that overflowed their banks and flood surrounding coastal lands [8]. In Nigeria, aside from droughts, floods cause almost 90 percent of damages resulting from natural hazards [1]. Floods that occur in Nigeria are as a result of extensive rainfall, drainage blockages and dam failures [8]. The effect of floods in Nigeria has been on the increase especially in the last three decades [8]. It has become a life-threatening concern to the citizenry and the number of deaths and damages caused by this perennial disaster are alarming [8]. Annually, more than 700,000 hectares of arable land and built up areas are damaged due to flooding in Nigeria [8]. Recorded damages include destruction of schools, houses built with mud brick and other traditional building materials, bridges, markets and washing away of agricultural lands [1]. Nigeria recorded its first flood in 1948 in Ibadan, capital of Oyo State, Since then, the menace has spread like wild fire to other states of the federation [8]. More than half of the thirty-six states in Nigeria have been hit by one form of flood or another [1], that occur along the Rivers Niger and Benue [8]. 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 part of Nigeria [1]; [8]. 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 rivers Challawa and Kano [8]. Twenty people were reported dead in Kano while 180 others were reported dead in Jigawa state [8]. A record of the total number of people affected by the flood incidence was well above 143,000 [8].

Four years later, precisely in August, 2005, the worst floods in forty years occurred in the northern city of Jalingo, the capital of Taraba state, after a heavy down pour of rain that lasted for eight hours [8]. Over 100 people were killed in the event and thousands of others displaced [8]. Similar incidence occurred in Zamfara state in September, 2006, when a torrential rainfall that lasted for 24 hours caused the collapse of a dam located outside the state's capital Gusau. The dam failure led to an influx of water into the nearby villages washing away hundreds of houses and destroying property worth millions of dollars [8]. The exceptionally heavy rainfall of August 2007 in Nigeria led to more than 46 deaths and displacement of over 2,500 families. The nine states that were seriously affected were Lagos, Ogun, Plateau, Nassarawa, Bauchi, Sokoto, Yobe, Borno and Kebbi. The floods were caused by poor drainage systems, ill-timed discharge of water from dams and the indiscriminate infrastructural development along river banks [9]. In 2010, dam failures as well as opening of flood gates and torrential rains all contributed to flooding in some northern states in Nigeria [9]. Over 2 million people and 5,000 villages were affected and about 50,000 families were left homeless [10]. s. Most recently in 2011, at least 102 deaths were recorded and 2,000 families were displaced in and around the south-western city of Ibadan as a result of floods from heavy rainfall that collapsed bridges and caused a dam to overflow [10]. In June, 2011, the ancient city of Kano experienced extensive rainfall which led to flooding in some parts of the city causing 24 deaths, collapse of houses and displacement of 700 people [11] In 2012 more than 7.7 million people were affected by flood in Nigeria more than 2.1 million registered with Internally Displaced Peoples Camps across the nation., 363 people were reported dead, about 600,000 homes were destroyed, out of 36 states in the country 32 were affected [10]. The flooding in Benue State in 2017 left over 100,000 people homeless in 24 communities including Makurdi and led to the loss of Billions of Naira worth of properties according to [12].

1.2 Flood Risk Management

"'Flood risk' means the combination of the probability of a flood event and of the potential adverse consequences for human health, the environment, cultural heritage and economic activity associated with a flood event" [3]. According to [13], flood risk is a product of hazard and vulnerability and a real risk level involves a certain level of hazard and vulnerability for a particular location. Flood risk management plans involve three phases including: preparedness, prevention and the mitigation phases [3]. The three stages in flood risk management are very essential for policy makers both at the national and international levels, as well as those responsible for making decisions at the state and local levels, relief and non-governmental organizations, consultants and producers (such as farmers) suppliers and traders. The preparedness phase would involve activities such as predicting and identification of zones or areas that have high risk and mapping of these vulnerable areas long before the flooding event occurs. The prevention phase would involve activities such as forecasting, early warning, observation and monitoring, and putting in place contingency plans in case of an eventuality. The final stage is the mitigation and response/reaction phase that handles activities after the disaster and this phase includes damage assessment and relief management [16]

Flood mitigation can be effective when areas vulnerable to flooding are identified and measures are put in place for preparedness, effective prevention and response. Identification of flood risk areas is of utmost important for policy planners and decision makers especially for management activities [16]. Such information is required by government and other relevant authorities for planning purposes and thus must be collated, processed and presented in a manner that can be understood by the public [7]. For an effective flood risk management, information on important indicators of flood risk are required [7]. Detailed knowledge about the issues such as rainfall distribution, demography of area, vulnerability of people, built-up areas, economic activities, frequency and magnitude of hazards in a potentially hazardous area is necessary for effective mitigation [15]. Scientific methods can be applied to this information to develop measures that would be useful in flood risk management. In the developed world, these measures are already in their implementation phase as is seen in the EU Floods Directive [3] but in Nigeria, management of floods is still in its policy level [5].

2. METHODOLOGY

The data used in this study were selected based on the following criteria:

i. Landsat ETM data acquired had cloud cover of less than 20%.
ii. ASTER GDEM data acquired had a 30m resolution and was geometrically process.
iii. The Landsat images was systematic terrain corrected (L1GT). This meant that the image was radiometrically and geometrically accurate.

2.1 Data Processing

The software used in data processing and analysis was Erdas Imaging and ESRI's ArcGIS 9.3. Uyo urban data in both vector and raster representation was acquired from the NASRDA, with the names of different street in Uyo urban. The analogue base map of the study area was scanned in raster format using the Hewlett Packard A0 Scanner. The file of the scanned image was exported to ArcGIS for georeferencing and onscreen digitization. The scanned base map was georeferenced and digitized onscreen using the ArcGIS 9.1. The features were digitized in layers, i.e., each group of features occupying each layer.

A stepwise arrangement and organisation of acquired data in a manner that was appropriate for analysis was used which started with Composite Band Formation the different bands in the Landsat image was composited in ArcGIS to produce an image with seven bands. Panchromatic sharpening was carried out which involved the fusion of the high resolution (15m) panchromatic band/image with the lower-resolution Landsat images. The Landsat 7 ETM+ composite image was pan-sharpened with panchromatic image. The composite image was clipped to the extent of the study area. Uyo urban map was also clipped. In order to carry out hydrology analysis on DEM, all depressions have to be filled. Such depressions are called sinks. The ASTER 30m GDEM sinks was filled using the 'Fill' tool in ArcGIS. The Uyo urban raster data was projected from Minna datum to UTM-WGS84 coordinate systems (as the other satellite image used in the analysis).

2.2 Data Analysis

Series of analysis was performed on the processed Landsat image, ASTER 30m GDEM and the Uyo urban data to generate flood risk maps, area at risk within the different flood risk zones as well as detection of changes in vegetation and land cover in the study area. The steps taken in the analysis include:

2.2.1 Supervised Classification

Classification of image is of two types: supervised and unsupervised and its objective is to designate classes to cells or pixels in a study area. Each class description relates to features/properties/characteristics/conditions of those cells that make it up [6]. When the features of pixels in an image are known, supervised classification is performed on the image but when the features are unknown, unsupervised classification is the alternative method [4]. Supervised classification was performed on the Landsat images as the features of the study area were known. The images were classified by grouping/clustering cells with the similar reflectance values. Four classes were generated from the classification namely: water bodies, farmland, built-up areas and vegetation as shown in fig

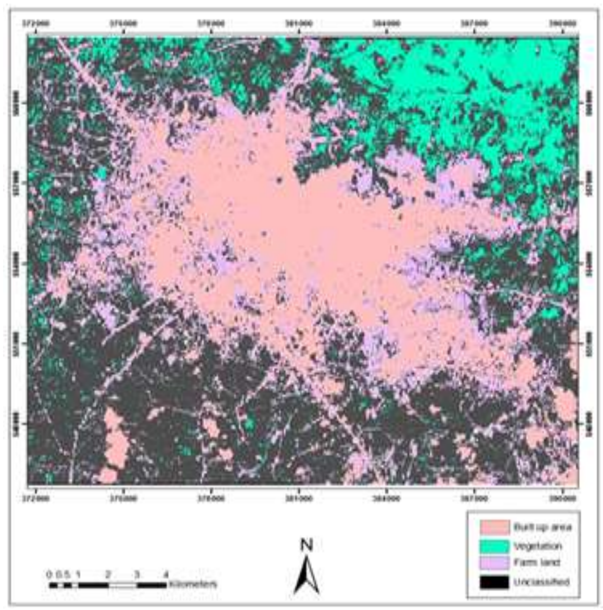

Fig 1: Supervised Classification of Landsat Image of Study Area.

2.2.2 ASTER 30M GDEM

Operations that was performed on the DEM to create risk zones. They include:

1. Delineation of Drainage Basins

Drainage basins are areas where all surface water flowing on the terrain flow out from a common outlet. Drainage basins have different properties and characteristics that affect their hydrology. [2]. Surface water on the landscape of a basin flow in stream channels and the characteristics of the basin such as its area and slope affect the extent and frequency of runoff and help to explain the likelihood of flooding in any particular basin. Understanding the risk of flooding in an area begins with knowledge of the mechanism of drainage basins and their stream networks [2]. The drainage basins in the study area was delineated using the basin tool in ArcGIS and further analysis was performed to understand the flow of water on the surface of these basins and then creation of stream channels.

2. Determination of Flow Direction

The depression less DEM was used to generate a flow direction raster. The flow direction shows the possible direction of water run-off on the elevation model. This analysis was performed using the flow direction tool in ArcToolbox's Spatial Analyst tools.

3. Determination of flow accumulation.

It shows the cells within the study area where water accumulates as it flows downwards. Thus, settlements around these cells will receive much water during an event of rainfall or any sudden release of water.

4. Creation of Stream Network and Buffer Zone

The stream network was created from the flow accumulation raster to show the path of streams on the elevation. A reclassification of the flow accumulation results was performed using the reclassification tool in Spatial Analyst tools. The result of the stream network analysis was reclassified to create a buffer zone around areas that are within 500m of the stream because of it closeness to major road, residential area and community land.

5. Calculation of Slope and Reclassification

The slope angles of the DEM were then calculated using the spatial analyst tools and a reclassification was performed to create three categories:

a) Areas with slope angles above 15.3 (High slope areas)
b) Areas with slope angles between 5.55 and 14.9 (medium slope areas)
c) Areas with slope angles below 0.5.54 (low slope areas)

The total areas occupied by these three categories were also determined.

6. Overlay of Layers and Production of Flood Risk Maps

After determination of slope and creation of stream buffer areas, the next major step is the addition of these two resultant layers in the raster calculator to produce a new layer showing three risk zones [2]. Areas within the stream buffer zone and in the low slope areas (High risk zone) Areas within the stream buffer zone and in the medium slope areas (Medium risk zone). Areas without the stream buffer zone and in the high slope areas (Low risk zone). The settlement layer, water bodies layer was overlaid with the risk zones layer to create flood risk maps ("A" and "B" "C") showing areas within the study area that are in the different risk zones.

3.RESULTS AND DISCUSSION

3.1 Flow Direction and Accumulation on DEM

Figure 2 is the result of the flow direction analysis carried out on the DEM.

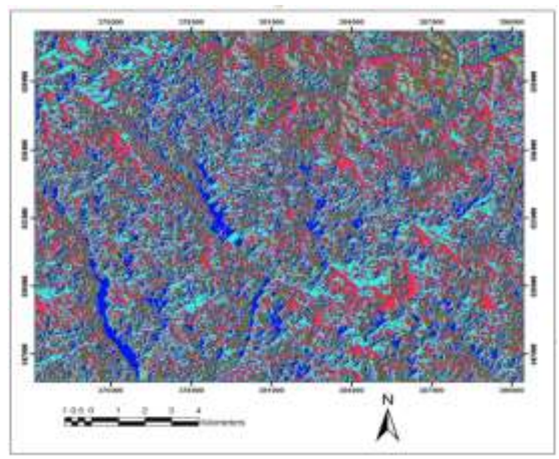

Fig 2: Diagram of Flow Direction on DEM of Study Area.

The diagram reveals a downward path for all water flowing on the surface of the area. Creation of the direction of flow on a surface elevation is the first step in process of producing stream networks in a study area. The flow direction would enable the determination of flow accumulation in different cells within the area. The cells that have the greatest accumulation of water flowing on the surface of the elevation model is shown in figure 3.

A total of 63 drainage basins were delineated in the study area. Five out of the nine major road in the study area are located within basins in the area. Fig 4 shows the result of delineation of drainage basins in the study area. Fig 5 shows the particular locations of the drainage basins on ground

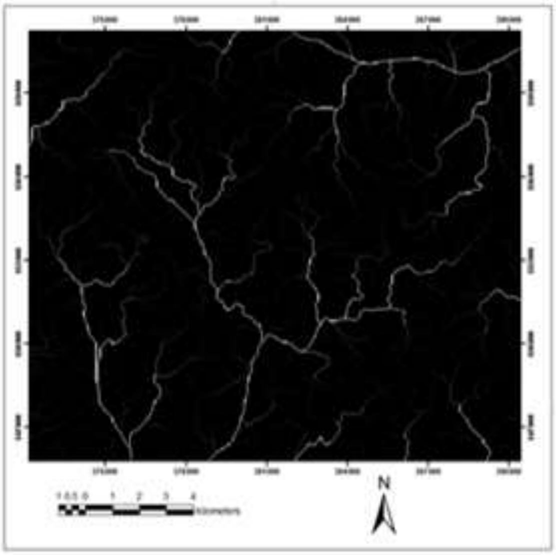

Fig 3: Diagram of Flow Accumulation on the Study Area

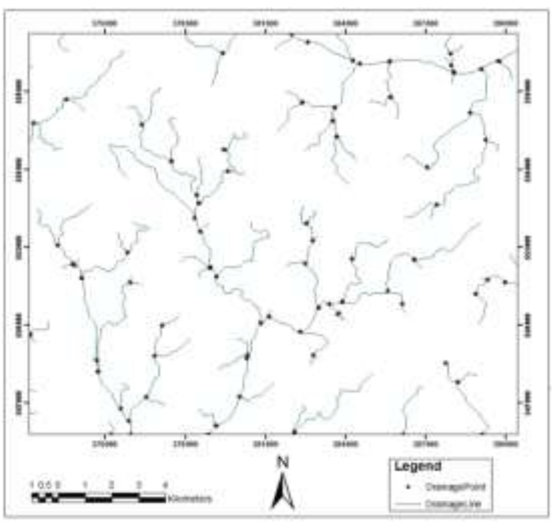

Fig 4: Drainage Basins in the Study Area.

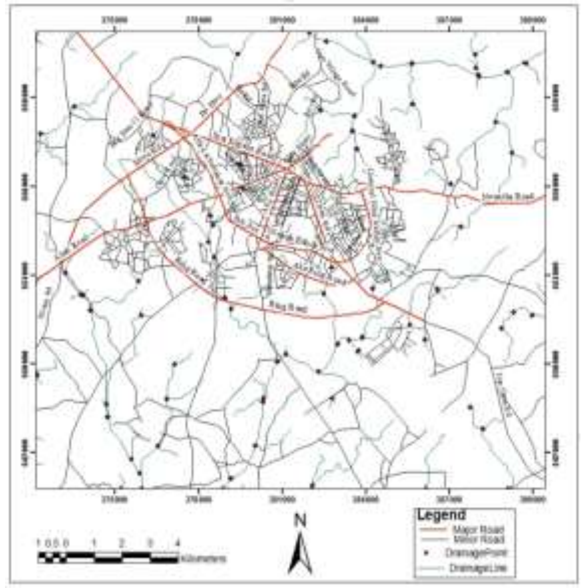

Fig 5: Drainage Basins superimposed on the Map of the Study Area.

The Map shows settlements scattered within the different zones. Majority of the settlements are within the heart of the city/metropolis. They are Ikot Ekpene Road, Abak Road, Aka Road, Nwaniba Road, Atiku Abubakar Road, IBB way, Idoro road, Nsikak Eduak road. Past flooding in Uyo Urban have always resulted in the loss of lives and properties [14]. People that would be affected live within flood prone areas. An understanding of the number of people that are likely to be affected during a flooding event will improve flood risk management. An estimate of area covered by flood within the study area was calculated based on the total area at risk within the study area. Table 1 show the results of the estimated area covered by flood within the different flood risk zones.

Table 1: estimated area within flood risk zones

Flood Risk Zones	Count	Total Estimated Area (sqm)	Area (%)
High	17891	87670800	52.50
Medium	16069	78738100	47.15
Low	1148	578200	0.34
Total	35108	166987100	100

The map of Uyo Urban distinguishes the different places in study areas within the risk zones. Figure 6, 7and 8 shows different flood risk zone maps of the study areas. The flood risk maps depict the areas within the study area that are most likely and unlikely to be inundated with water in a flooding event.

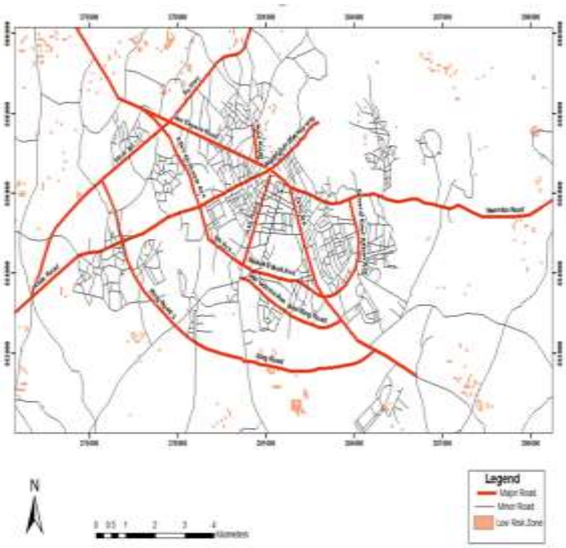

Fig 6: Flood Risk Map A of Study area showing Low Risk Zone.

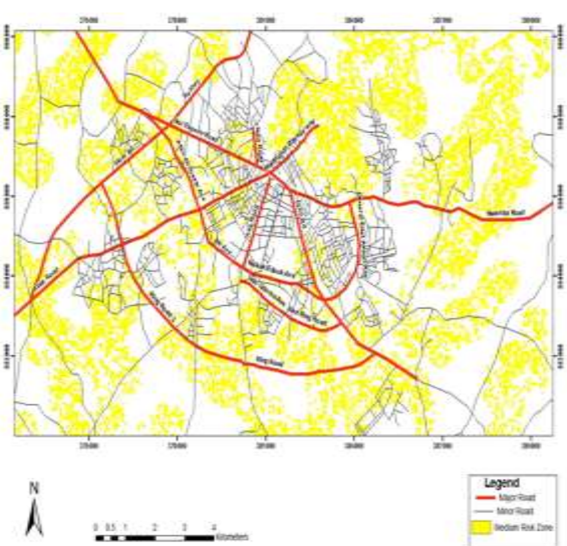

Fig 7: Flood Risk Map B of Study area showing Medium Risk Zone.

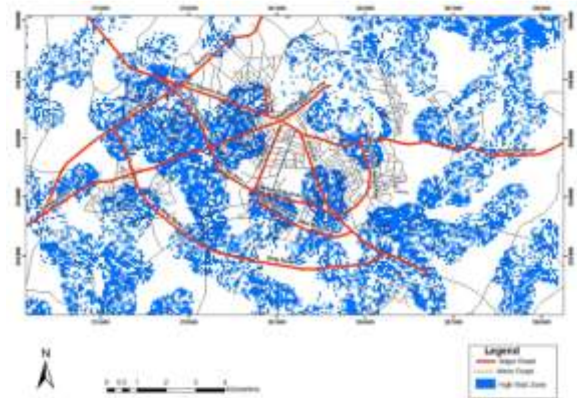

Fig 8: Flood Risk Map C of Study area showing High Risk Zone.

A total of 8,767,080sq km (52.50%) of the area fell within the high flood risk zone, 7,873,810sq km (47.15%) of the area in the medium risk zone while 5,78200sq km (0.34%) of the area fell within the low risk zone. 80.1% of the total area is built-up and inhabited, this area is described as the metropolis and the centre of major urban activities in Uyo Urban. The results show the effect of migration of people from rural areas to urban areas in search of better standard of living. The cluster of settlements within this urban area could increase the death rates in a flooding episode especially when proper rescue measures are not put in place.

CONCLUSION

This study has expounded the importance and usefulness of GIS in flood risk management and the ease of developing flood risk maps for different ecological zones and urban areas The making available spatial information for future references. A total of 63 drainage basins were delineated and the stream network on the landscape of this area was carved. A combination of the stream network and the slope of the area were used in developing flood risk zones for the city. Three zones were specified: high, medium and low flood risk zones. It was concluded from this study that Land cover changes play a vital role in increasing the vulnerability of the area to flooding, the supervised classification of Landsat imagery used, showed the percentage changes all inform of the reduction in vegetation cover in the area which in effect exposes the area to increase in surface runoff and possible overflow of low lying areas. The physical properties of the areas also contribute to increase or decrease in surface runoff.

Furthermore, it was concluded that the factors that influence flooding significantly in this region are population explosion and urbanization. Significant growth in population over the years, resulted to increased human activities and environmental degradation (vegetation lose and deforestation) therefore the vulnerability of the area to flooding is significantly increased.

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