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GIS Analysis of Flood Vulnerable Area in Benin–Owena River Basin Nigeria

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Abstract The frequency and intensity of flood disasters have become serious issues in the national development process of Nigeria as flood disasters have caused serious environmental damages, loss of human lives and other heavy economic losses; putting the issue of disaster reduction and risk management higher on the policy agenda of affected governments, multilateral agencies and NGOs. The starting point of concrete flood disaster mitigation efforts is to identify the areas with higher risk levels and fashion out appropriate preventive and response mechanisms. This research paper explored the potentials of Geographic Information System (GIS) in data capture, processing and analysis in identifying flood-prone areas for the purpose of planning for disaster mitigation and preparedness, using Benin-Owena river basin of Nigeria as a unit of analysis. The data used in this study were obtained from FORMECU and were entered and use to develop a flood risk information system. Analysis and capability of the developed system was illustrated and shown

Keywords: Flood, Geographical Information System (GIS) Risk, River -Basin, Vulnerability

Abstrak *Frekuensi dan intensitas bencana banjir telah menjadi masalah serius dalam proses pembangunan nasional di Nigeria seperti bencana banjir yang menyebabkan kerusakan lingkungan yang serius, hilangnya nyawa manusia dan kerugian ekonomi yang berat; penempatan isu tentang pengurangan bencana dan manajemen risiko lebih tinggi daripada rencana kebijakan pemerintah yang terkena dampak, lembaga multilateral, dan LSM. Titik awal upaya mitigasi bencana adalah untuk mengidentifikasi area yang memiliki tingkat risiko lebih tinggi dan membentuk mekanisme pencegahan dan respon yang sesuai. Laporan penelitian ini menyelidiki kesanggupan Sistem Informasi Geografi (SIG) dalam pengambilan data, pengolahan, dan analisis dalam mengindentifikasi daerah rawan bencana yang menjadi tujuan dari perencanaan mitigasi bencana dan kesiapsiagaan, menggunakan Daerah Aliran Sungai Benin-Owena di Nigeria sebagai unit analisis. Data yang digunakan dalam penelitian ini diperoleh dari FORMECU dan telah dimasukkan dan digunakan untuk mengembangkan sistem informasi risiko banjir. Analisis dan kemampuan dari sistem yang dikembangkan digambarkan dan ditunjukkan melalui grafis. Penelitian menunjukkan lebih dari seribu pemukiman di daerah penelitian menyimpan sepuluh juta penduduk berisiko terhadap banjir.*

Kata kunci: Banjir, Daerah Aliran Sungai, Kerentanan, Risiko, Sistem Informasi Geografi,

1. Introduction

Flooding is a major risk to riversides populations and floodplains causing substantial impacts on the environment, including aquatic fauna and flora, bank erosion and other aspects due to the infrastructure such as dams, piers, and lands as well as by poor development practices including riverside development, excessive cleaning, encroachment upon water ways, dredging which may cause changes in the hydrological balance of the water ways involved [Nolan and Marron, 1995]. Worldwide, there has been rapid growth in number of people killed or seriously impacted by flood disasters [UN-Water, 2011]. Indeed, the amount of economic damages affects a large proportion of people in low-lying coastal zones or other areas at risk of flooding and extreme weather condition. According to UN-Water [2011] flood is seen to have caused about half of disasters worldwide, and 84% disaster deaths in the world was attributed to flooding. Askew [1999] reiterated that floods cause about one third of all deaths, one third of all injuries and one third of all damages from natural disasters.

The primary cause of flooding in many parts of the world according to the Action Aid ;[2006] is directly or indirectly related to rainfall in the catchment areas of the major river systems. The unpredictability of rainfall in recent times has caused untold hardship during the raining season. However, flooding is not only related to heavy rainfall and extreme climatic events Action Aid [2006]; it is also related to changes in the built up areas themselves. Potschin [2009] asserted that land use is an important determinant of the state of the natural environment. Millennium Ecosystem Assessment MA [2005], for example, has shown that at global scales the conversion of ecosystems through human activities has adversely affected not only biodiversity but a range of ecosystem services. Urban areas such as Lagos, Port Harcourt, Kano, Ibadan, and Benin in Nigeria has always present some risk of flooding when rainfall occurs. Prevailing uncoordinated and uncontrolled urban growth allows for buildings or infrastructure to be constructed that actually obstruct natural drainage channels [Aina et al., 1994 ; Aina, 1995].

A study by Action Aid, Unjust Waters Action Aid

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[2008], documents the lack of provision in six African cities including Lagos, Nigeria for reducing flood risks or for managing floods when they happen. Urbanization aggravates flooding by restricting where flood water can go, by covering large parts of the ground with roofs, roads and pavements, by obstructing sections of natural channels and by building drain that ensure that water moves to rivers more rapidly them it did under natural conditions. At extreme cases of flood, many abandon their houses and completely relocate to other areas that are not affected by flood. Some others live in their houses for few months of the year during the dry season, after which they relocate and come back when another dry season begins. The money that would have been spent to improve the standard of living in the home is spent by families to relocate, helping to further impoverish the people. Shelter is one of the basic needs of man. In some other instances where the affected people cannot relocate, they are forced to live with the flood. This makes them vulnerable to various water-borne diseases such as malaria, diarrhoea, cholera and typhoid fever. Trauma resulting from the circumstance can also cause non-pathogenic diseases such as high blood pressure and diabetes Etiosa and Ogbeibu [2006].

The month of July in Nigeria, which is one of the peak periods of rains have continued to be dreaded by the residents of the flood prone areas within major river basins and cities such as Lagos, Port Harcourt and Benin. For instance, an extreme 10 hours rainfall in Port Harcourt on July, 14 2006 drove ten thousand residents out of their home and caused wide spread traffic chaos. The flood problems was aggravated by structures such as the Port Harcourt-Patani - Warri Highway that cut across natural drainage lines and acts as a barriers flood waters [Abam et al. 2000]. Similarly, on the 15th of July 2010, the people in the cities of Lagos and Abeokuta were gripped with shock and stunned seeing the havoc wreaked by torrential rain. The heavy downpour rendered thousands of people homeless and dispossessed them of their valuables, so many roads and bridges were also seriously damaged.

The flooding was aggravated by the release of water from the Oyan Dam near Abeokuta, which was filled beyond capacity by the high volume of water from the heavy rainfall in the area. In Nigeria, several studies of the hydrological changes associated with urbanization Akintola [1994] have described the contributions of topographic conditions, rainfall characteristics, land use changes (especially the expansion pave impermeable areas), uncontrolled waste dumping and construction on the floodplain, to lead local flooding [Oriola, 1994]. The roles of rainfall amount and intensity have also been well discussed [Olaniran and Babatolu, 1996].The perception of impact adjustment to flooding in Nigeria have been extensively studied [Olorogunorisa, 1999]. Heavy rains accompanied by thunderstorms appear to be on the increase in most areas probably because built up surfaces attain higher temperature than surrounding areas. It is very important to have sound and effective flood management and control measures because floods impose a curse on the society and proper management and control of its occurrence is of vital importance. This is only feasible if there are proper and effective flood hazard maps of the area for proper decision making [Sedogo, 2002; McCall, 2008; Rambaldi et al. 2006]. In the absence of accurate and up-to-date information on issues such as flood hazard and vulnerability, decision-makers often fail to make decisions or make incorrect decisions [Haack, 1982]. Flood hazard mapping is a vital component in flood mitigation measures; control and land use planning, and is also an important prerequisite for the flood insurance schemes in flood-prone areas [Okosun et al., 2009]. It creates easily-read, rapidly-accessible charts and maps which facilitates the administrators and planners to identify areas of risk and prioritize their mitigation/ response efforts. Such maps are very helpful in planning and decision making process as the identified sensitive areas can be avoided from being developed. If the area must be developed, flood hazard maps can act as guidelines to further justify the type of development that is to be implemented. GIS applications in flood risk mapping range from storing and managing hydrological data to generating flood inundation and hazard maps to assist flood risk management.

Over the last decade in particular, a great deal of knowledge and experience has been gained in using GIS in flood risk mapping. The basic applications of GIS for hazard and vulnerability mapping as well as identification of coping mechanisms, overall risk, urban hazards and conflict mapping can be found [McCall, 2008]. Recognizing the importance of up-to-date base maps for effective planning, there is need to utilize the opportunities facilitated by modern geospatial technology through the integration of satellite images with GIS for the production of such maps with high accuracy for the cities of this country. Remote Sensing and other sources are importnat in solivng and reducing the risk of flood hazards. There is an urgent need to include the concepts of disaster geo-information management into emergency preparedness planning, spatial planning and environmental impact assessment. In developing countries like Nigeria, the advantages of flood risk-related spatial information within a GIS context have not been widely explored. There is a need to convert raw data into useful spatial information that allows the community and other actors to develop analytical processes for flood risk analysis and exploration of risk reduction alternatives [Maskrey, 1998; IFRC, 2005].

The aim of this study is to identify flood- prone areas for the purpose of planning for disaster mitigation and preparedness, using Benin- Owena river basin, Nigeria as a unit of analysis. The specific objectives of the study are as follows: 1) to identify the areas that are at risk of flooding using GIS techniques, 2) to identify and detail those factors that are relevant to current and future flood risks in the study area, 3) to examine the impact on and vulnerabilities of residents in the study area to the increasing risk of floods, and 4) to outline policies to be applied to such areas to minimise and manage flood risk.

2. The Methods

The Benin-Owena River Basin is one of the twelve river basin authorities created as part of the Nigeria's Third National Development Plan in 1977 [Federal Government of Nigeria (FGN), 1975]. Located between longitudes 5o-6o 40I E and latitude 5-70 40I N, the basin is well drained with an average surface slope of

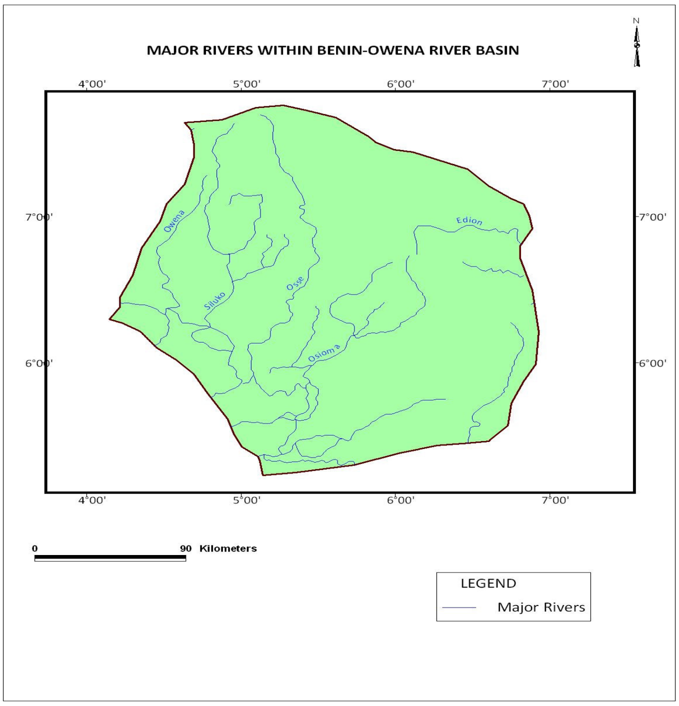

Figure 1. A digital map showing the drainage within Benin-Owena River Basin.

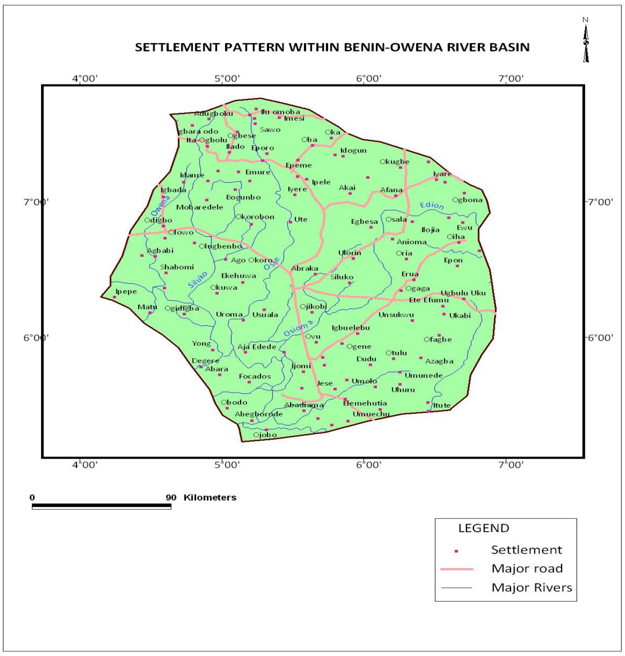

Figure 2. A digital map showing the administrative boundary of Benin-Owena River Basin.

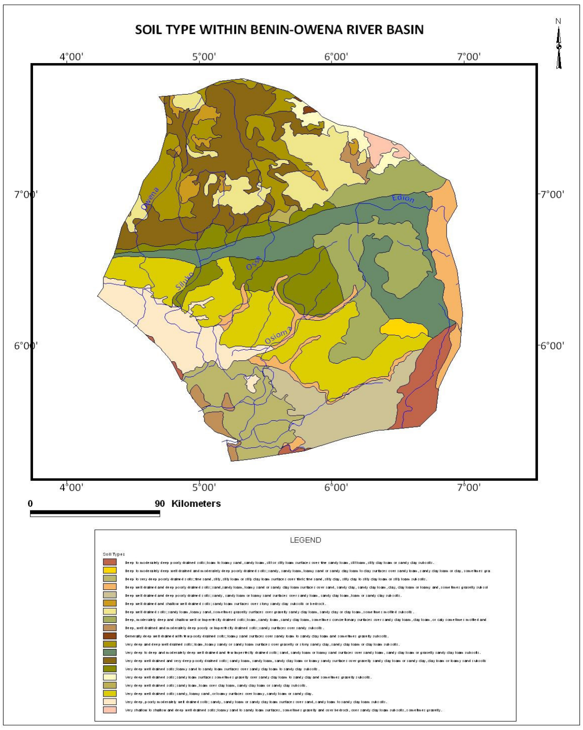

Figure 3. A digital map showing the administrative boundary of Benin-Owena River Basin.

0-6%. Geologically, the basin is within two broad parts- the basement complex rocks of the north with little or no prospect for exploitable groundwater and sedimentary rocks of the south with relatively high groundwater potential. The soils are Oxisols in the south and Utisols in the north. The hydrology is a reflection of the geology and is dominated by the extensive River Niger flood plain in the east and other rivers such as the Ubo, Edion,Orle, Okhuamahun and Owena. The average monthly rainfall ranges from 27mm in December to 365mm in July with a mean annual rainfall of 2165m.

The study relies on spatial data obtained from FORMECU. Elevation data for the region was derived from the STRM data which was downloaded from their website. Digitized drainage (figure 1) and administrative boundary maps (figure 2), soil type map (figure 3), and land use map (figure 4) alongside the Digital Elevation Model form the input into the flood risk analysis. These data are complemented by attribute data like rainfall and population data, obtained mostly from archival sources. Spatial data from satellite images were georeferenced and existing digital data transformed to the WGS_1984 Projection System. This was done to allow for consistency and avoid representation errors that may arise from differing spatial extent of these data. The attribute most especially the population and rainfall data were joined to spatial data based on common fields to further improve the usefulness of the spatial data.

Rainfall data were obtained from Nigeria Meteorological Agency. Drainage map of the study area was produced from vectorization of the scanned topographical maps of the area and re-projected the data to WGS_1984. Settlement data were obtained from the settlement delineation study conducted by the Nigeria Communication Commission conducted in 2005 which remains the most comprehensive settlement data in the country till date. Soil types and land use data were obtained from digital vector data from FORMECU, a Federal Government Department in charge of forest management.

3. Result and Discussion

The data analysis for this study was essentially carried out within GIS framework, using ESRI's ArcGIS 10.0TM. Three major variables were used to determine the risk exposure to flooding in the study area. From literature, it is apparent that relief, hydrology and human activities are risk factors in flooding [Ologunorisa, 2006]. Each of the three variables was categorized into three major categories-high, medium and low risk factors.

The study area is for the most part a lowland area made up of flood plain of major rivers. This informed the choice of the decision variables for delineating the area into high, medium and low flood risk areas. Since the rainfall regime is essentially the same for most parts of the study area, it was excluded from the decision variables. Generally, areas with height less than 268 metres were designated as high risk areas; areas with height between 268.1 and 280 metres were described as medium or moderate risk areas while areas above

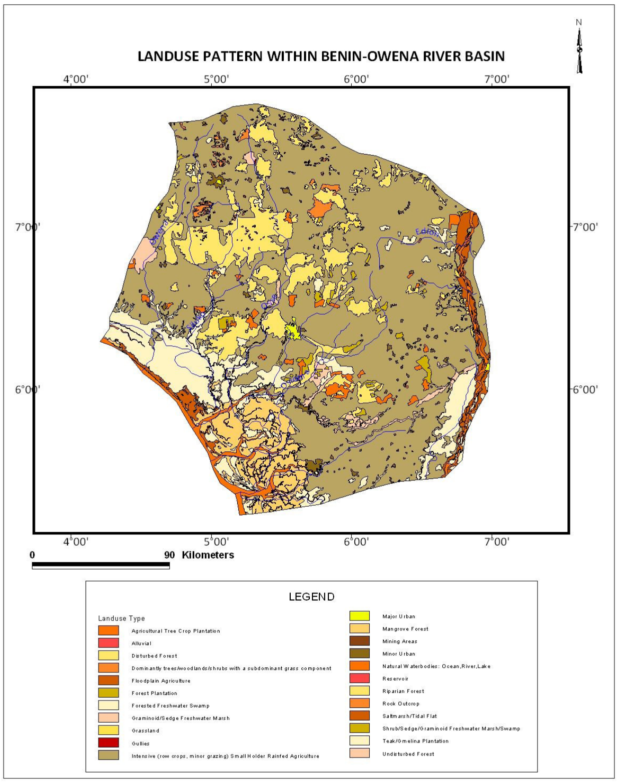

Figure 4. A digital map showing the administrative boundary of Benin-Owena River Basin

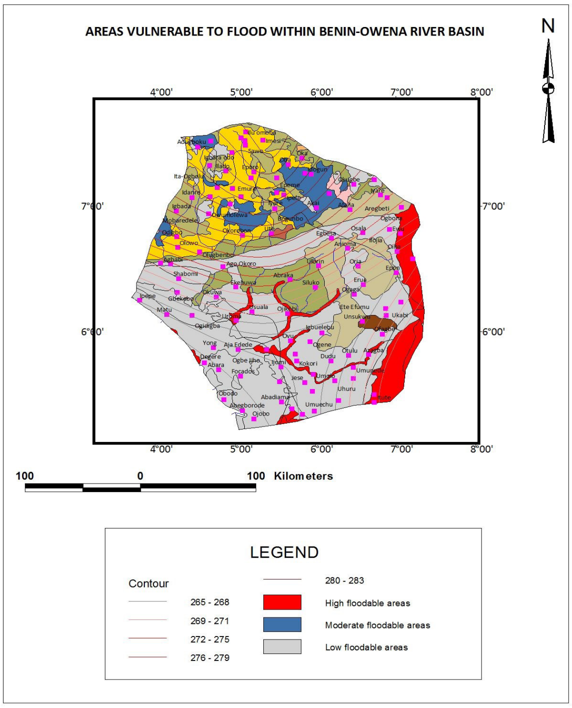

Figure 5. A digital map showing areas vulnerable to flood within Benin-Owena River Basin.

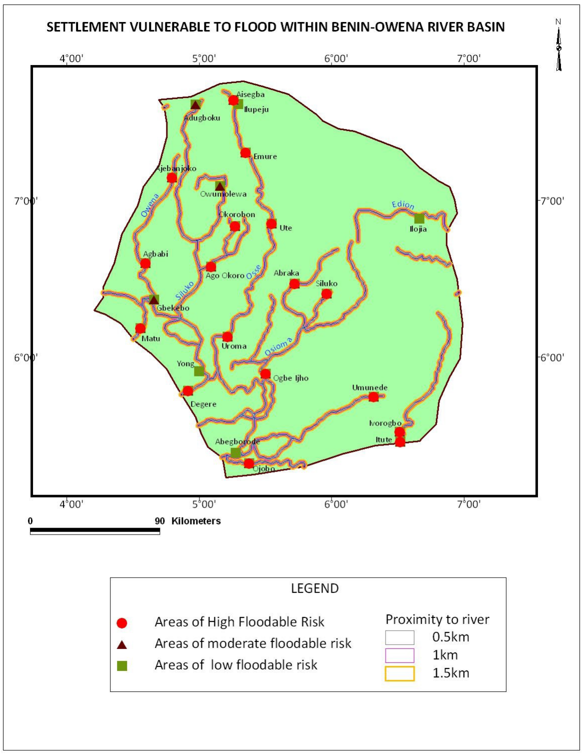

Figure 6: A digital map showing proximity of settlements within the river basin to drainage channels.

280metres are designated as low risk areas (see figure 5).

Proximity to river channels is an important variable in this study. Distance from rivers and their tributaries were reckoned at 0.5,1.0 and 1.5km, with areas within 0.5km of river channels were categorized as high risk areas; areas within 0.5-1.0km as medium risk areas and areas located at over 1.0km to the river channels were described as low risk areas (see figure 6).

5. Conclusion

This study has attempted an assessment of flood risk in Benin-Owena River Basin. The study reveals that over 1,000 settlemnts harbouring over 15million people are at grave risk of flooding. It is therefore imperative the policies aimed at mitigating the effect of flooding be strictly implemented in order to forestall losses in human lives and material possession.

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